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ALLATOONA LAKE DESTRATIFICATION EQUIPMENT TEST REPORT

Army Engineer District

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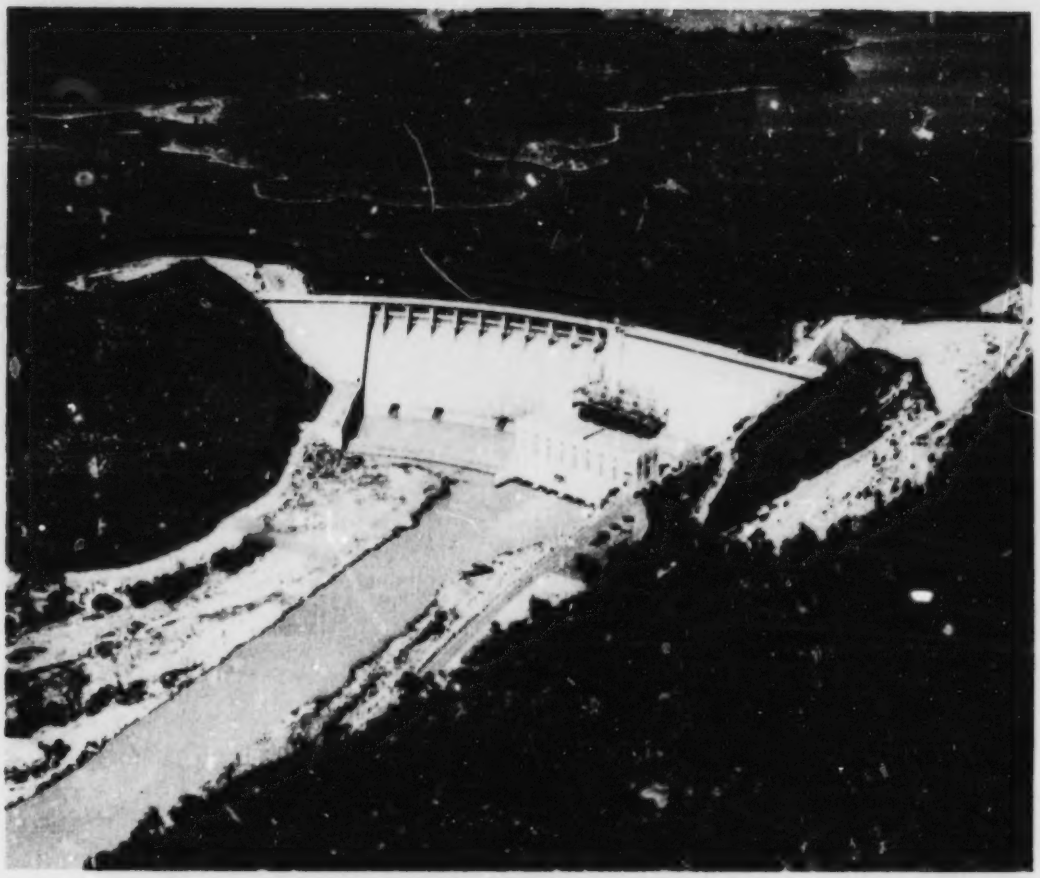

ALLATOONA DAM

ALLATOONA LAKE

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ACKNOWLEDGEMENTS

The Savannah District greatly appreciates the assistance and cooperation provided in this study by the Georgia Department of Public Health, the Georgia Fish and Game Division and the Environmental Protection Division of the Georgia Department of Natural Resources, the Surveillance and Analysis Division of Region IV of the Environmental Protection Agency (EPA), the U.S. Public Health Service, and the U.S. Army Engineer District, Mobile. The technical assistance provided by Associated Water and Air Resources Engineers, Nashville, Tennessee, and Dr. James M. Symons, National Environmental Research Center, Cincinnati, Ohio, are greatly appreciated.

SUMMARY AND CONCLUSIONS

The experimental field investigation reported herein was conducted at the Allatoona Lake Project during 1968, 1969, and 1970 to determine the effects resulting from operation of destratification equipment, specifically a diffused air pump, on the water quality of Allatoona Lake and releases therefrom, and to develop criteria for design and operation of similar equipment at other impoundment projects. The diffused air pump was located about 2,000 feet upstream from the Allatoona Dam.

The diffused air pump was operated at about 80 percent capacity from 9 May through 30 September 1968 and at full capacity from 17 March through 10 September 1969, during which time, observations were made of the physical, chemical, biological and bacteriological water quality of the Allatoona Project. Similar water quality observations were made during 1970 without operation of the diffused air pump.

The evaluations presented in this report are concerned primarily with the effects of the diffused air pump operation on the water quality of the Allatoona Lake in the vicinity of the Allatoona Dam. The data for these evaluations and additional data obtained at the Allatoona Project during this investigation are included in the Appendices. The destratification results were evaluated using available data of the Allatoona Project for 1966 and 1970, a mathematical model for predicting water temperature and a multiple regression model for predicting dissolved oxygen.

Dissolved oxygen isopleths of the Allatoona Lake showed that the diffused air pump operation possibly affected dissolved oxygen concentrations in a zone extending about four miles upstream from the Allatoona Dam. Efforts were made to further determine the zone of influence of the diffused air pump; however, these studies were only partially successful and the specific zone of influence remains unclearly defined.

In the vicinity of the Allatoona Lake near the dam, during both years of operation of the diffused air pump, dissolved oxygen concentrations were increased at depths from 30 to 80 feet, with some increase in dissolved oxygen at depths below 80 feet, particularly during the 1969 operation of the diffused air pump. Dissolved oxygen concentrations were slightly depressed in the top 10 to 20 feet depth. Fall overturn, which usually occurs about mid October, was observed during late August and early September 1968 and 1969. In early September, when dissolved oxygen is normally low, or absent except in the epilimnion, during 1968 and 1969 dissolved oxygen became uniformly mixed in the lake at concentrations of 4 to 6 MG/L to depths of about 100 feet. Water temperatures were generally decreased in the top 10 to 20 feet depth with increased water temperatures below the 30 feet depth.

The dissolved oxygen content of peak flow generation releases from the Allatoona Dam powerhouse exceeded 4 MG/L except for July and August 1968.

In 1969, when the diffused air pump was operated starting in the early spring, the dissolved oxygen content of peak flows exceeded 4 MG/L during the entire summer and fall periods. The dissolved oxygen content of low flow generation releases exceeded 4 MG/L during 1968 and 1969, except for about one week in late August. The temperature of generation releases were increased about 2 to 4° Centigrade during the months of June through August 1968 and 1969.

Comparisons in water quality data of the Allatoona Lake near the dam for 1968, 1969 and 1970 showed that the diffused air pump operation possibly resulted in an increase in concentrations of carbon dioxide, kjeldahl nitrogen, and ammonia nitrogen with a decrease in total hardness, conductivity, turbidity, total iron, total and dissolved manganese, and nitrate + nitrite nitrogen. Dissolved iron appeared to be appreciably reduced in the hypolimnion during August, the month of extreme stratification. The operation of the diffused air pump did not appear to significantly affect total alkalinity, total and dissolved phosphates, or pH. Differences in environmental conditions during 1968, 1969 and 1970 may have had some effect on these observations, i.e.; weather, especially precipitation, wind, and solar radiation or cloud cover.

The diffused air pump operation reduced the stability, or intensity of thermal stratification in the Allatoona Lake. The thermal destratification efficiency achieved during 1968 and 1969 was about 0.3 to 0.7 percent, respectively, with an oxygenation capacity of about 1.0 pound dissolved oxygen per kilowatt hour energy input. Expected efficiency had been estimated at 1.0 to 2.0 percent.

The operation of the diffused air pump seemingly had little short term effect on the benthic and planktonic communities within the lake These effects appeared restricted to the area surrounding the diffuser units. The most noteworthy biological change was the appearance of freshwater jellyfish surrounding the diffuser units in September. These jellyfish apparently were feeding on the midge larvae transported upward in the air column. Results of their predation were reflected in a "reduced" benthic community near the diffuser units. (See page 51)

Qualitative studies of the benthic biota downstream from the Allatoona Dam indicated a more diverse community during 1968 and 1969, possibly from the increased dissolved oxygen in the releases from Allatoona Lake.

Bacteriological data obtained in the Allatoona Lake near the diffuser units did not show any significant effect of artificial destratification on coliform density, or vertical distribution of these bacteria.

Total cost of equipment, materials, and labor to install the diffused air pump was about $85,000. Estimated annual operating costs, based on six months of continuous operation and a 5 year amortization of initial investment cost at 5 1/2 percent interest, are about $31,000.

INTRODUCTION

Since the 1952 work of Hooper, Ball and Tanner in Michigan, various types of mechanical destratification equipment have been used in a variety of lakes. The objective of most of these installations has been to artifically destratify these bodies of water thereby preventing, or overcoming some deterioration in water quality that resulted from the natural phenomena of thermal stratification. The basic principle of artificial destratification is to supply sufficient energy, over that naturally available, to destratify the lake in a manner similar to that which occurs during fall overturn.

Some dams of deep manmade lakes are designed for hydropower production with less expensive more efficient, low level intakes to the generators. During the stratification period water released from these intakes may be void of oxygen, high in iron and manganese and of a low temperature. This quality of water, though desirable for cooling purposes, is not suitable for most aquatic life and may cause water treatment problems where water supply systems are involved.

Water resource planners and designers are faced with the problem of predicting and controlling the quality of impounded and released water. In reality, there are many unknowns as to the physical, chemical, biological, and bacteriological characteristics of existing streams and impoundments. These can be determined only by continued study of existing streams and impounded water.

Allatoona Lake Project

Allatoona Lake was completed in 1955 and is located about 30 miles northwest of Atlanta, Georgia. It is a multipurpose project providing for flood control, hydroelectric power generation and related water uses. Although authorized primarily for flood control and power generation, it will also aid in regulating streamflow and provide additional benefits for recreation. The 190 foot high dam creates a lake with a surface area of 11,860 acres and a volume of 367,500 acre feet at a normal pool level of 840 feet msl. Water depths near the dam are 150 feet, and the lake, with one major arm, backs water up the Etowah River for a distance of 28 miles. The Allatoona Dam powerhouse consists of two 36,000 kilowatt main units and one 2,000 kilowatt service unit for a total capacity of 74,000 kilowatts. The main unit penstocks are 20 feet in diameter with the centerline of the intakes 90 feet below the normal summer pool level of 840 msl. The service unit penstock is 5.5 feet in diameter with its centerline 55 feet below the normal summer pool level. Downstream releases from the generation units vary from a minimum of 200 cfs for the service unit to about 4,000 cfs each for the main units. A map of the Allatoona Lake and section of the Allatoona Dam powerhouse are shown in Figures 1 and 2.

FIGURE 1. Allatoona Lake Project.

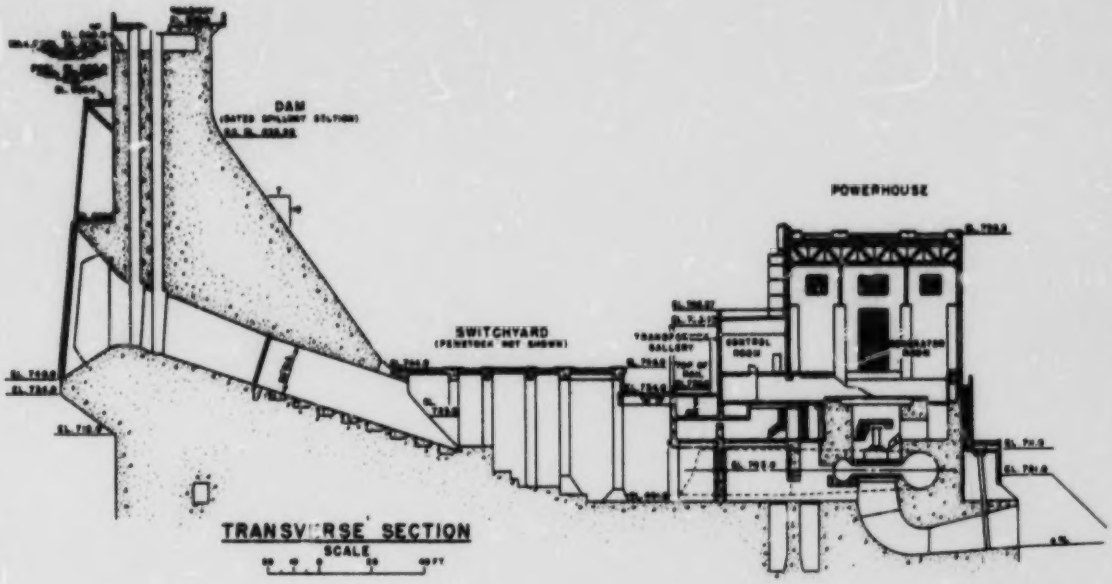

FIGURE 2. Section of Allatoona Dam Powerhouse.

Description of Diffused Air Pump System

The diffused air pump system consists of five cross shaped diffuser units and five sixty horsepower, electrically powered, rotary type compressors as shown in Figure 3. Each compressor has a minimum capacity of 250 cfs free air at 100 psig. Air flow from the compressors was piped through a manifold with a flow rate controller on each of the five, two inch diameter galvanized steel pipe lines to the diffuser units as shown in Figure 4. A two inch plastic pressure hose was used for connecting the galvanized steel pipe line to the diffuser unit. The diffuser units are suspended ten feet above the bottom of the lake by a buoy, anchor and cable system as shown in Figure 5. Forty air diffuser tubes were used on each diffuser unit as shown in Figure 6. The diffuser tubes have a length of 24-1/16" and an outside diameter of 3 inches, with a corrugated metal core covered by 1/16" diameter saran cord. The air compressors are equipped with oil separators and air filters to prevent clogging of the air diffusers. A diffuser unit and installation of an air supply line to the diffuser unit are shown in Figures 7 and 8, respectively.

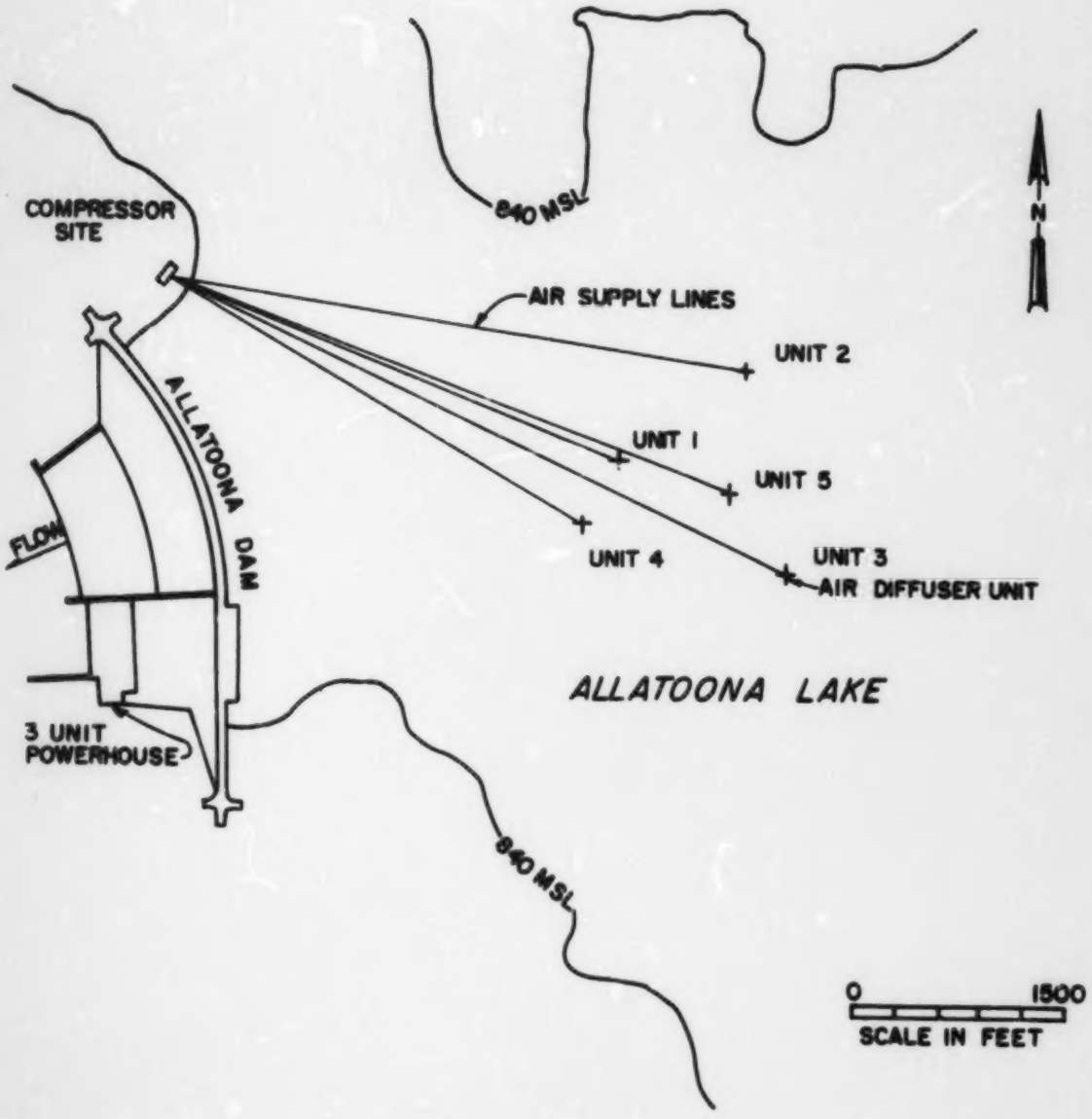

FIGURE 3. Location of Air Diffuser Units

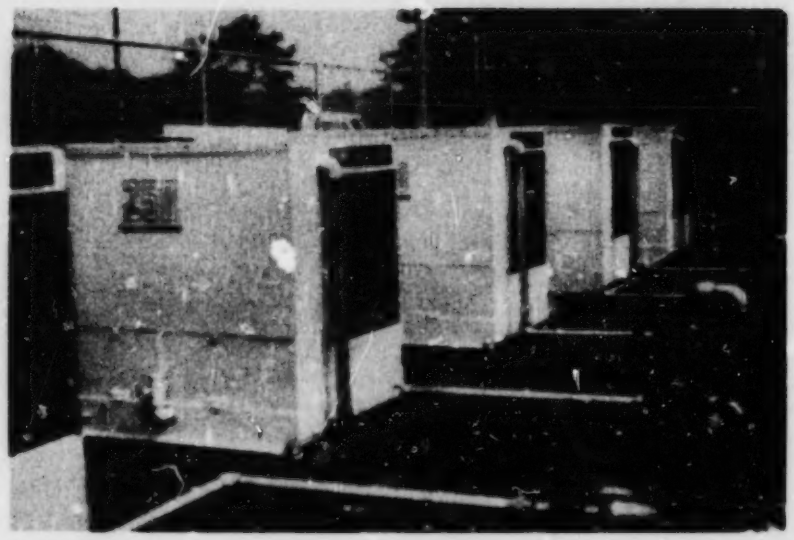

FIGURE 4. Electric Compressors.

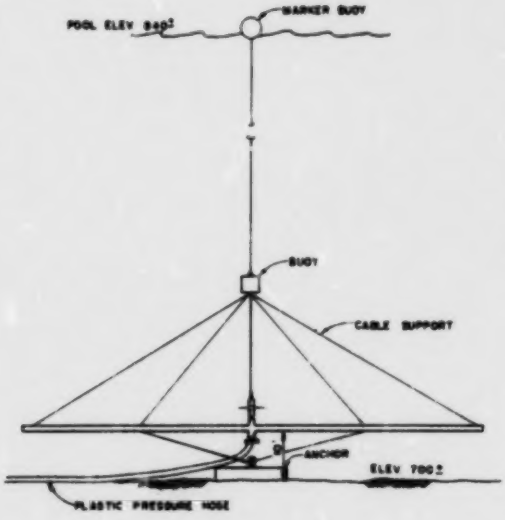

FIGURE 5. Air Diffuser Unit Elevation.

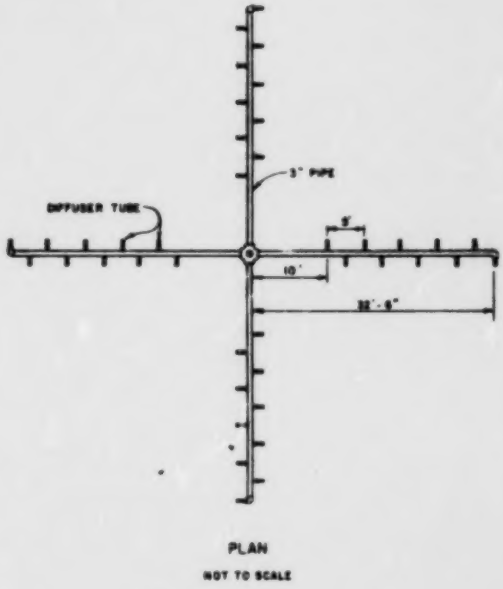

FIGURE 6. Air Diffuser Unit Plan.

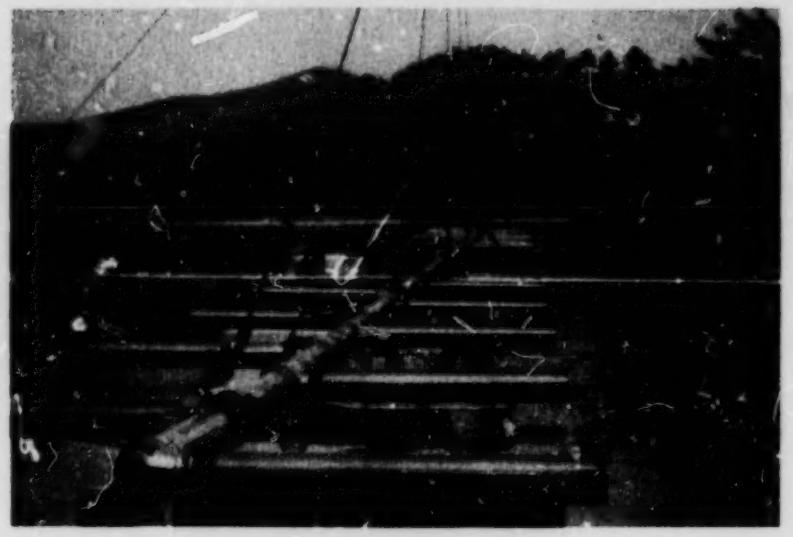

FIGURE 7. Diffuser Unit.

FIGURE 8. Installation of Air Supply Line to Air Diffuser Unit.

Equipment Operation

The diffused air pump was placed in operation 9 May 1968. During the period from 9 May through 11 August 1968, one compressor was inoperative because of the inadequate capacity of a circuit breaker. In 1969, all five compressors were operated continuously from 17 March through 30 September, except for short periods of servicing and maintenance. The air compressors utilized a total of 693,760 kilowatt hours electrical energy during 1968 and 1,091,840 kilowatt hours in 1969. The "boils" at the lake surface from the diffused air pump operation is shown in Figure 9.

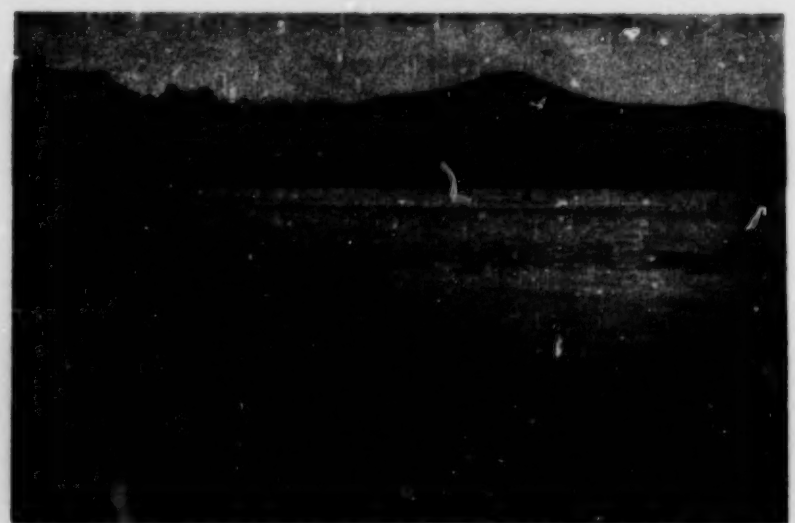

FIGURE 9. Boils at Lake Surface from Diffused Air Pump Operation.

Water Quality Investigations

The location of stations in which water quality investigations were performed during this study are shown in Figure 10. During the spring, summer and fall of 1968, 1969, and 1970, chemical, biological and bacteriological water quality surveys were made by staff from Region IV, of the Environmental Protection Agency. The mobile laboratory used for these investigations is shown in Figure 11. Additional temperature, dissolved oxygen, pH, conductivity, turbidity, iron and manganese data were obtained by the Corps of Engineers. A continuous recording water quality monitor was installed 0.4 mile downstream from the dam for measuring water temperature, dissolved oxygen, pH and conductivity. In 1969 and 1970, a weather station was installed on the lake for measuring wind velocity, air temperature, and relative humidity. Water quality and operational data for the Allatoona Project for 1968, 1969 and 1970 are contained in Appendices A, B, and C, respectively.

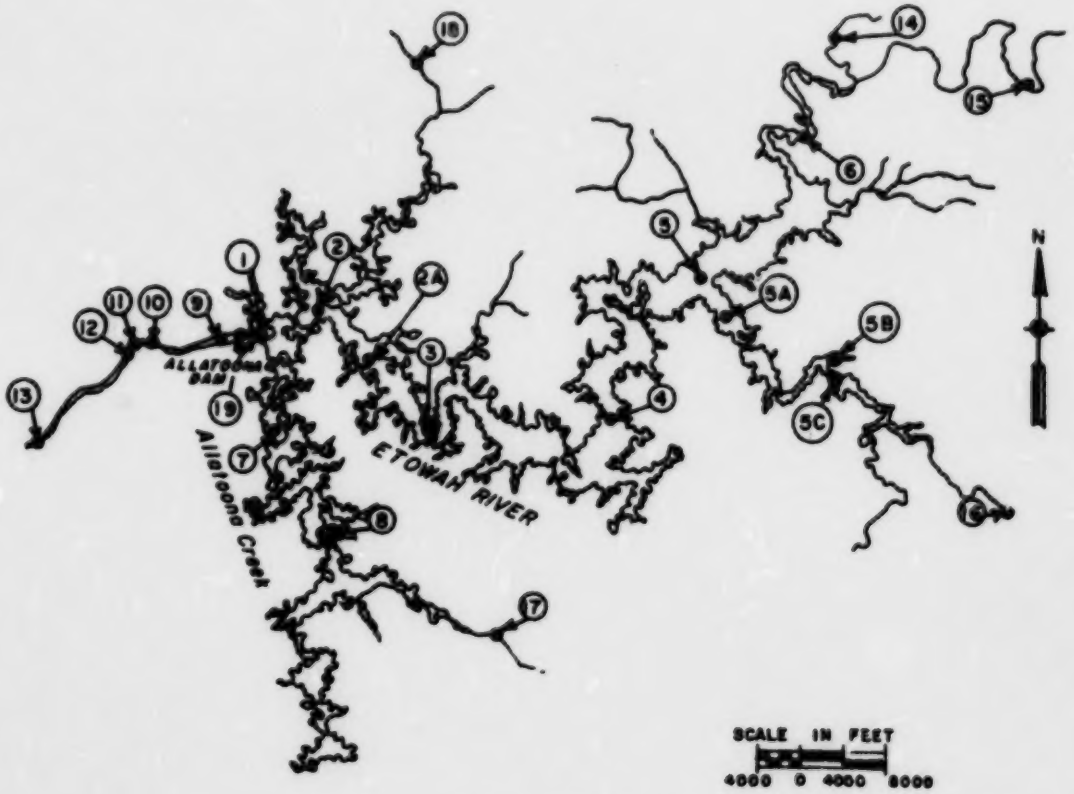

FIGURE 10. Water Quality Sampling Stations.

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FIGURE 11. Mobile Laboratory of EPA, Region IV.

Analytical Procedures

Water quality analytical procedures were performed as prescribed in "Standard Methods for the Examination of Water and Wastewater" with a few exceptions. Electronic temperature meters and a bathythermograph were used to obtain water temperature. Total and dissolved iron and manganese samples were filtered through a 450 millimicron "Millipore" filter immediately after obtaining the sample and sulfuric acid was added to both the filtered and unfiltered portions for preservation. Total iron and manganese were determined from the unfiltered portion and the dissolved iron and manganese from the filtered portion by atomic absorption. Chemical analyses and methodology are shown in Table 1.

TABLE 1

Chemical Analyses and Methodology

Name of Analyses	Method of Determination
The following constituents are in MG/L.	
Dissolved Oxygen	Azide "Alsterburg"
Total Iron (Fe)	Atomic Absorption
Dissolved Iron (Fe)	Atomic Absorption
Total Manganese (Mn)	Atomic Absorption
Dissolved Manganese	Atomic Absorption
BOD_2	Azide "Alsterburg"
BOD_5	Azide "Alsterburg"
Total Hardness as $CaCO_3$(TH)	EDTA Titrimetric
Total Alkalinity as $CaCO_3$(TA)	Titrimetric (Indicator)
Sulfide (S)	Methylene Blue Visual Color-Match
Carbon Dioxide (CO_2)	Titrimetric (Std. NaOH)
Total Phosphate as P (TP)	Technicon Auto Analyzer
Dissolved Phosphate as P (DP)	Technicon Auto Analyzer
Kjeldahl Nitrogen	Technicon Auto Analyzer
NH_3 Nitrogen	Technicon Auto Analyzer
NO_3 + NO_2 Nitrogen	Technicon Auto Analyzer
COD	Dichromate Reflux & Titration
The following are not MG/L.	
Color	Platinum Cobalt
pH	pH Meter
Turbidity (JCU)	Turbidity Meter
Conductivity (UMHO)	Conductivity Meter

Basic Data

Prior to 1968, studies were made to assemble data on water quality, water uses, sources of pollution and the effects of the Allatoona Project on downstream water quality. Pre and post impoundment water quality data for the project were obtained in 1949 and 1950 by the Environmental Health Center of the U.S. Public Health Service. In 1962, the U.S. Public Health Service conducted some water quality investigations at the Allatoona Lake to determine the extent of interstate pollution of the Coosa River. From 1964 through 1966, the Corps of Engineers obtained water temperature, dissolved oxygen, pH, iron and manganese data usually two or three times monthly, at Station 1 and several downstream stations. Chemical analyses of these data were performed the same as in 1968, 1969 and 1970 studies with the exception that iron and manganese samples were filtered through a 100 millimicron "Millipore" filter and analyzed in accordance with colorimetric procedures described in "Standard Methods for the Examination of Water and Wastewater". Additional water quality data for Allatoona Lake were obtained by the Federal Water Pollution Control Administration in 1966.

CRITERIA FOR EVALUATION OF THE EFFECTS OF THE DIFFUSED AIR PUMP OPERATION

Analysis of data from other artificial destratification projects has shown that the major influence on water quality caused by artificial mixing relates to one or more of the following six parameters, temperature, dissolved oxygen, and their related parameters, iron, manganese, hydrogen sulfide, and plankton. By pumping cold water to the surface and mixing it with the surface layers so that it does not sink back down into the hypolimnion, the lower waters are warmed and the water body will approach a uniform temperature throughout its depth. In addition, if dissolved oxygen is absent from the hypolimnion, and the reduced forms of iron, manganese, and/or hydrogen sulfide are present, pumping this water to the surface where it can contact the atmosphere will provide a source of oxygen for the oxidation of these reduced materials. If, on the other hand, some dissolved oxygen is originally present in the hypolimnion, but its concentration is less than saturation, bringing this water to the surface for contact with the atmosphere will enhance reaeration, thereby raising the dissolved oxygen concentration as well as the total quantity of dissolved oxygen in the lake. If the mixing of the water body is sufficently rapid, plankton counts may be lowered and the dominant plankton type changed from bluegreen to green algae. The mechanism causing this change in plankton population is not precisely known at this time (1972) but seems to be related to turbulence and the alternating light and dark environments to which the plankton are subjected during rapid mixing. Slow gentle mixing does not have this same effect, but in some cases actually may enhance plankton populations. Thus, in the evaluation of an artificial destratification project, these six are the major water quality parameters that should be examined.

The major question that exists when the evaluation of an artificial destratification project is attempted, is what should be used as a control for evaluation of the destratification results. This question arises no matter what water quality parameter is chosen for evaluation.

One method of establishing a control is to use the basic data available of the water quality of the project without operation of the destratification equipment; however, some year to year variation almost always exists in the concentration of any parameter. Therefore, choosing the proper year which the destratification results should be contrasted may be difficult. Whether a certain year's data are arbitrarily chosen, or the average concentration of the water quality parameter for the period of record is chosen as the control, the actual water quality of the lake had it not been mixed may always be questionable.

Historical Control

Water quality data of the Allatoona Project without operation of the diffused air pump for 1964 through 1966 and 1970 showed that during the summer months, thermal stratification occurred in Allatoona Lake, resulting in a severe reduction of dissolved oxygen in the hypolimnion. Temperature stratification began in the impoundment with the warming of lake surface in

early March and rapidly increased until mid July, with some slight reversals during rain, or extended cool weather. In mid August, temperature stratification started receding and the lake attained nearly uniform temperatures from top to bottom in late October.

From 1964 through 1966 and during 1970, water temperatures of the Allatoona Lake at Station 1 were about the same each year at depths below 40 feet. Dissolved oxygen concentrations were within about 1 MG/L each year at depths from 40 to 80 feet. Total iron concentrations fluctuated considerably. From 1964 through 1966, dissolved iron concentrations decreased each year with an increase in total and dissolved manganese concentrations. Statistical analyses of iron and manganese data for 1964 through 1966 and 1970 showed that comparisons of these data could not be made due to differences in sample analyses by colorimetric and atomic absorption techniques as previously discussed.

From the above analyses of the water quality of the Allatoona Lake without operation of the diffused air pump, the data for 1966 and 1970 were used for evaluation of the destratification results. Operational and meteorological data for the Allatoona Project for 1966, 1968, 1969 and 1970 are summarized in Tables 2 and 3. One major difference between 1966 and 1970 operations of the Allatoona Lake was that in 1970, the pool levels varied to about six feet below the 1966 levels.

Mathematical Predictive Techniques

In this investigation, two types of mathematical models were used to provide an additional control for evaluation of the influence of the diffused air pump operation on water temperature and dissolved oxygen.

Temperature Model of Allatoona Lake

A theoretical model was developed for predicting water temperatures of the Allatoona Project based upon meteorological conditions and inflowing water temperatures. This is discussed in Appendix D. In this case, the model developed by Associated Water and Air Resources Engineers, Inc., Nashville, Tennessee, was checked using data taken during the summer of 1970, when the diffused air pump was not operated. The model was then used to generate water temperatures that would have occurred in 1969.

TABLE 2

ALLATOONA LAKE PROJECT

OPERATIONAL DATA

	Average Pool Elevation (MSL)				Average Tailwater Elevation (MSL)				Average Discharge (CFS)				Average Total Inflow (CFS)			
	70	69	68	66	70	69	68	66	70	69	68	66	70	69	68	66
March	832.89	832.89	835.33	839.11	690.70	690.76	691.45	692.67	1349.9	1443.5	2502.0	4146.4	2461.0	2217.9	3219.3	3980.4
April	837 94	838.34	838.12	838.16	690.64	691.24	691.18	690.81	1268.1	2172.6	2161.7	1382.9	1902.1	3081.4	3068.4	3104.9
May	839.75	840.03	840.08	843.20	690.55	691.05	691.24	692.13	1139.3	1857.4	2205.0	3398.8	1196.5	2019.5	2236.2	3107.9
June	839.75	840.17	840.28	840.05	691.05	690.52	690.73	691.24	1665.1	1048.0	1329.6	2014.2	1687.8	1117.1	1339.8	1447.7
July	837 49	839.92	840.24	839.00	690.73	690.35	690.55	690.78	1250.0	798.7	1081.9	1186.2	777.1	748.4	1017.6	918.0
August	834.74	839.77	839.37	837.07	690.23	691.00	690.45	690.80	1447.7	1857.4	956.2	1375.7	795.0	1909.9	617.4	981.0
September	829.64	839.57	838.00	834.00	690.72	690.63	690.49	690.61	1320.1	1247.1	1056.3	1247.3	449.0	1007.0	788.5	627.7
October	827.12	836.83	834.69	832.62	690.30	690.93	690.74	690.49	698.8	1737.6	1440.8	993.6	1049.2	677.9	552.3	1223.6
Average for Period	834.90	838.32	838.26	837.90	690.61	690.80	690.86	691.20	1265.5	1505.8	1594.8	1973.3	1264.5	1578.1	1606.7	1926.3

TABLE 3

ALLATOONA LAKE PROJECT

METEOROLOGICAL DATA AT ALLATOONA DAMSITE

	Average Precipitation (INS)				Average Pan Evaporation (INS)				Average Maximum Air Temperature (C)				Average Minimum Air Temperature (C)			
	70	69	68	66	70	69	68	66	70	69	68	66	70	69	68	66
March	0.20	0.13	0.12	0.16	0.13	0.11	0.13	0.14	17.3	14.1	18.1	17.8	3.1	0.3	1.3	2.5
April	0.15	0.15	0.20	0.23	0.15	0.16	0.13	0.16	24.0	23.4	22.1	22.5	10.1	9.3	8.6	8.2
May	0.06	0.15	0.26	0.16	0.17	0.19	0.19	0.16	27.5	26.1	25.6	24.5	13.3	13.4	12.1	13.1
June	0.16	0.05	0.03	0.04	0.18	0.21	0.18	0.22	28.9	31.3	30.3	29.1	17.0	18.3	16.6	16.6
July	0.21	0.15	0.19	0.06	0.21	0.24	0.18	0.22	31.9	33.7	31.1	31.4	18.9	20.7	19.2	19.8
August	0.10	0.16	0.02	0.24	0.17	0.16	0.21	0.18	30.9	29.6	32.2	30.0	20.0	19.0	19.8	18.8
September	0.13	0.16	0.08	0.09	0.17	0.13	0.15	0.14	30.2	26.5	27.0	26.6	18.4	15.9	15.3	15.8
October	0.28	0.03	0.06	0.18	0.10	0.10	0.10	0.12	22.4	21.1	21.6	22.0	11.6	10.7	9.7	8.0
Average for Period	0.16	0.12	0.12	0.14	0.16	0.16	0.16	0.17	26.6	25.7	26.0	25.5	14.0	13.4	12.8	12.8

Dissolved Oxygen Model of Allatoona Lake

A multiple regression model was developed for predicting the dissolved oxygen concentrations which would have occurred at the Allatoona Lake during March through October 1968 and 1969 without operation of the diffused air pump. An equation was derived for each 10 foot incremental depth of the lake, the difference in dissolved oxygen concentrations between 1966 and 1970 at each depth as a function of dissolved oxygen concentrations for 1966 and the difference in the following variables on a daily basis:

Average Pool Elevation (MSL)
Average Inflow (CFS)
Average Outflow (CFS)
Maximum and Minimum Air Temperature (C)
Pan Evaporation (INS)
Dissolved Oxygen Saturation Value of Water at Maximum and Minimum Air Temperatures (MG/L)

The hypothesis for development of the regression model was that the daily dissolved oxygen concentrations of the Allatoona Lake for a given year would be the same as observed during a previous year, if environmental conditions and project operations of these years were identical. Daily dissolved oxygen data used in development of the regression model were interpreted from observed dissolved oxygen data of the Allatoona Lake at Station 1 for 1966 and 1970. Changes in waste loading to the lake from 1966 through 1970 were considered to be reflected in the dissolved oxygen data of these years. The multiple regression correlation coefficients for the equations varied from .941 to .996 with a maximum residual of about 1.5 MG/L.

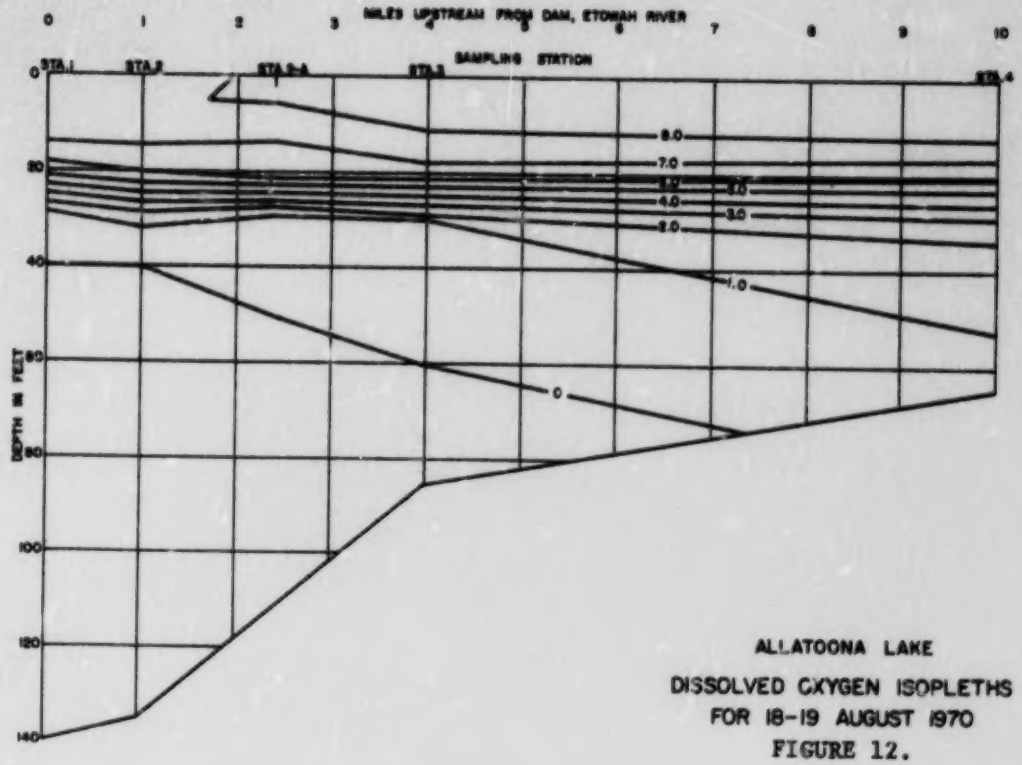
This regression model has the disadvantage that it is only applicable to the body of water in question, but it has the advantage of using actual field data, rather than attempting to model a complex natural phenomenon theoretically. Unfortunately, dissolved oxygen data were available to confirm the regression model only for April and May 1968, and July 1971. While the model seemed to be reasonably accurate in predicting dissolved oxygen concentrations, a full year confirmation would have improved its credibility.

The above discussed model was developed after Associated Water and Air Resources Engineers, Inc., found that they were unable to produce a theoretical model for dissolved oxygen due to the lack of input data required. (See p. 77 of Appendix D). They were not able to write a series of chemical and mathematical equations to describe completely what changes take place in a given parcel of water as it passes through a reservoir. Additional studies are needed on organic material to determine depletion factors.

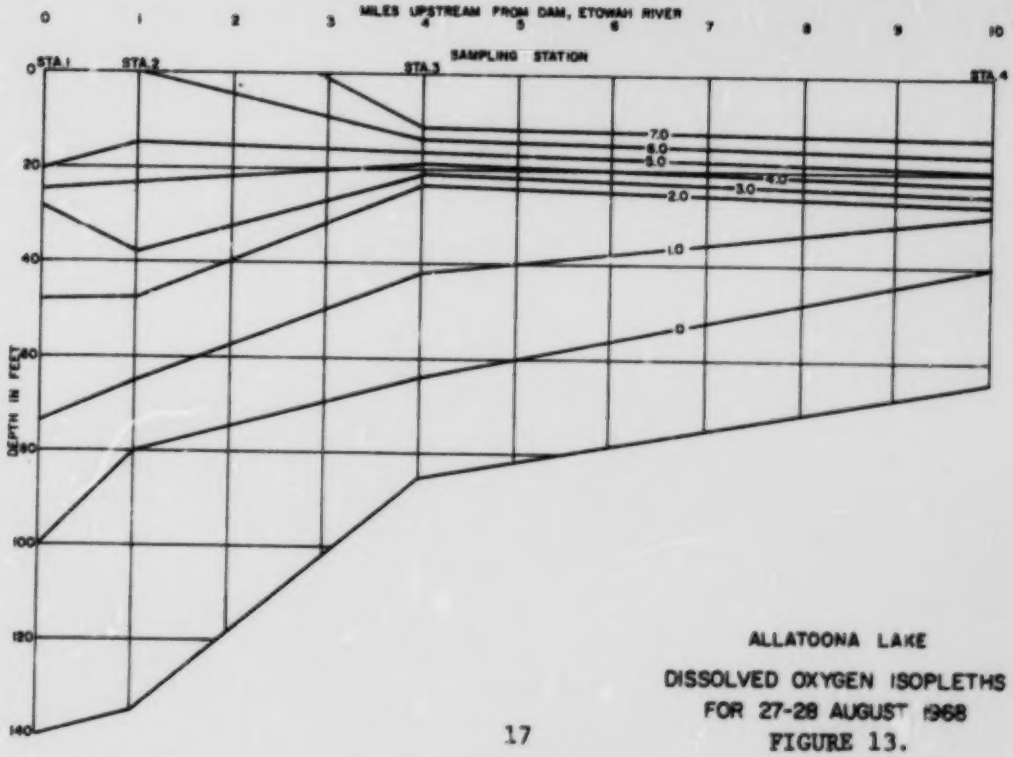
ZONE OF INFLUENCE OF DIFFUSED AIR PUMP

An attempt was made to define the zone of influence of the diffused air pump operation by injecting fluorescent dye into Allatoona Lake at the diffuser units and following the travel of the dye. In terms of the initial objective, this study was only partially successful. Dye was shown to have traveled in all directions away from the injection site, but the extreme limits of the zone of influence remain undefined. The successful accomplishment of the objective of the dye study was greatly hindered by the location which required the use of very small quantities of dye to protect the City of Cartersville water supply.

Figure 12 shows that during mid August when the diffused air pump was not operated, the dissolved oxygen isopleths were fairly horizontal. Comparing Figure 12 with Figure 13, the dissolved oxygen isopleths for late August 1968 shows that the diffused air pump operation possibly influenced dissolved oxygen concentrations at least as far upstream from the dam as Station 3 (4 miles) but not as far as Station 4 (10 miles).



ALLATOONA LAKE
DISSOLVED OXYGEN ISOPLETHS
FOR 18-19 AUGUST 1970
FIGURE 12.



ALLATOONA LAKE
DISSOLVED OXYGEN ISOPLETHS
FOR 27-28 AUGUST 1968
FIGURE 13.

PHYSICAL AND CHEMICAL ANALYSES AND EVALUATIONS

Allatoona Lake

Water Temperature

In both years operation of the diffused air pump, water temperatures were generally decreased in the top 10 to 20 feet depth of the lake at Station 1, with increased water temperatures below the 30 foot depth as shown by the temperature profiles in Figures 14 and 15. The water temperatures of the lake were about the same during 1969 as were observed in 1968. The similarities of the lake water temperatures during 1968 and 1969 indicate that the 1968 operation of the diffused air pump had about the same influence on water temperatures of the lake as the 1969 operation of the destratification equipment.

Dissolved Oxygen

A noticeable increase in dissolved oxygen concentrations of the Allatoona Lake at Station 1 were observed during 1968 and 1969 at depths from 30 to 80 feet, with some improvement of dissolved oxygen at depths below 80 feet, particularly during the 1969 operation, as shown in Figures 16 through 18. Dissolved oxygen concentrations were decreased in the top 10 to 20 feet depth. In early September, when dissolved oxygen is normally low or absent, except in the epilimnion, during 1968 and 1969, it became uniformly mixed in the lake at concentrations of 4 to 6 MG/L to depths of about 100 feet.

Other Parameters

Figures 19 through 33 show that at Station 1, during 1968 and 1969 as compared to 1970, total hardness, conductivity, turbidity, total iron, total and dissolved manganese and nitrate + nitrite nitrogen were somewhat less, with an increase in carbon dioxide, kjeldahl nitrogen and ammonia nitrogen. Whether the difference in these parameters can be attributed to the operation of the diffused air pump, and/or yearly variations in the water quality of the Allatoona Lake is not entirely known at this time.

Total alkalinity, total and dissolved phosphates, and pH were about the same during 1968 and 1969, as 1970. Dissolved iron appeared to be appreciably reduced in the hypolimnion during August, the month of most extreme stratification.

Allatoona Dam Releases

Temperature and Dissolved Oxygen

During both years operation of the diffused air pump, the temperature of generation releases from the Allatoona Dam Powerhouse were increased about 2 to 4° Centigrade for the months of June through August. These increased temperatures appeared to extend only for a short distance downstream from the Allatoona Dam without any apparent detrimental effect on downstream water uses.

The dissolved oxygen content of peak flows during 1968 exceeded 4 MG/L except for the months of July and August. In 1969, when the diffused air pump was operated starting in the early spring, the dissolved oxygen content of peak flows exceeded 4 MG/L during the entire summer and full periods. The dissolved oxygen content of low flow releases exceeded 4 MG/L during 1968 and 1969, except for about one week in late August.

During the months of June through mid September 1970, the dissolved oxygen content of low flows decreased from about 4 to 0.05 MG/L and from about 4 to 0.4 MG/L on peak flows. During May through October of 1966, the dissolved oxygen content of low flows ranged from 7.5 to 0.7 MG/L, with dissolved oxygen concentrations less than .4 MG/L for three months.

The computer program, "Selective Withdrawal From a Density Stratified Reservoir through a Submerged Orifice", developed by Waterways Experiment Station, Vicksburg, Mississippi, was used for predicting the temperature and dissolved oxygen concentrations which would have occurred during 1969 for peak and low flow generation releases without operation of the diffused air pump. Input data for this program consisted of observed operational data of the Allatoona Dam Powerhouse and the predicted water temperature and dissolved oxygen regression model data of the Allatoona Lake for 1969 as previously discussed. The temperature and dissolved oxygen concentrations predicted by this program as compared to observed 1969 data are shown in Table 4.

In general, the water temperatures of releases during the 1969 tests showed a 1 to 2° Centigrade increase during July and August at the tailrace. At stations 1.9, 2.4, and 4.6 miles downstream, no significant changes in water temperatures were observed.

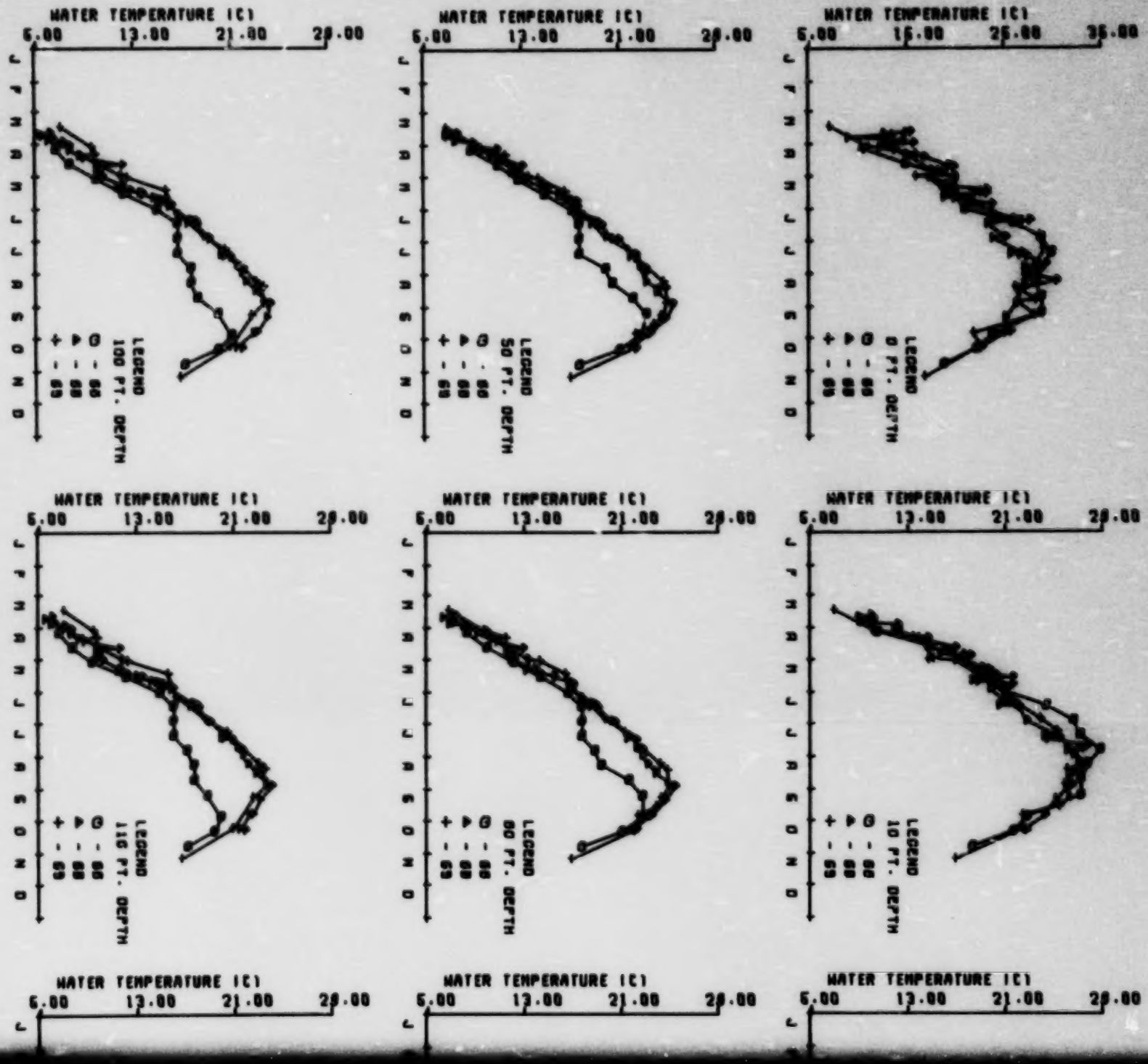
Dissolved oxygen of releases showed a 1 to 2 mg/l increase in the tailrace throughout the 1969 test period, and as much as a 4 mg/l increase during low flows in August and September. Only slight or negligible increases were observed at stations more than two miles downstream.

TABLE 4

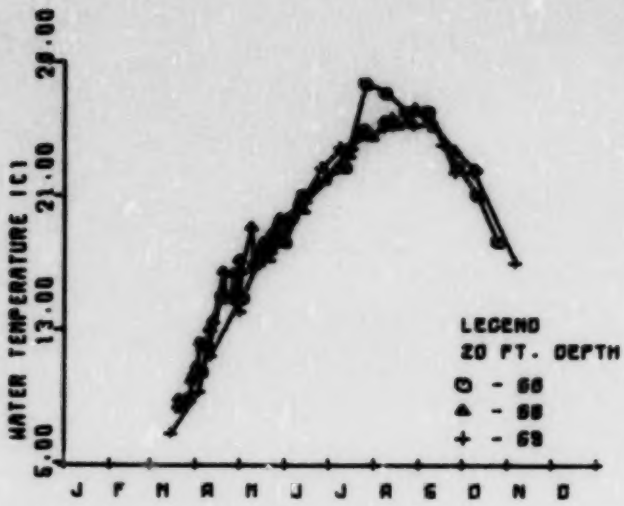
OBSERVED & PREDICTED
TEMPERATURE & DISSOLVED OXYGEN
OF RELEASES FROM ALLATOONA POWERHOUSE FOR 1969

Date	LOW FLOW				PEAK FLOW			
	Temperature (C)		Dissolved Oxygen (MG/L)		Temperature (C)		Dissolved Oxygen (MG/L)	
	Observed	Predicted*	Observed	Predicted*	Observed	Predicted*	Observed	Predicted*
14 Mar 69	--	7.3	--	11.6	--	7.3	--	11.6
10 Apr 69	10.2	10.1	11.0	10.1	--	9.6	--	9.9
29 Apr 69	13.2	12.6	9.7	8.5	13.2	12.4	9.6	8.3
13 May 69	--	14.0	--	7.1	--	13.0	--	6.9
4 Jun 69	17.2	16.0	8.0	5.3	17.3	14.8	6.?	4.7
25 Jun 69	19.5	17.7	5.7	3.1	19.7	17.0	6.2	2.8
8 Jul 69	22.5	18.9	4.7	1.7	22.5	18.9	4.2	1.7
13 Aug 69	23.9	21.7	3.1	0.1	24.4	20.5	4.5	0.2
25 Aug 69	--	22.6	--	0.1	24.5	21.4	5.2	0.5
8 Sep 69	24.2	23.3	4.1	0.1	24.3	22.3	4.2	0.6
16 Sep 69	--	23.4	--	0.7	--	22.7	--	0.7
25 Sep 69	--	22.6	--	1.4	--	22.2	--	1.5
7 Oct 69	22.0	22.2	6.5	3.6	22.0	21.6	6.2	2.3
24 Oct 69	--	21.6	--	6.2	--	21.0	--	5.8

* Without mixing


WATER TEMPERATURE (C)
6.00
13.00
21.00
29.00
J F M A M J J A S O N D
LEGEND
100 FT. DEPTH
O - 66
▲ - 68
+ - 69
WATER TEMPERATURE (C)
6.00
13.00
21.00
29.00
J F M A M J J A S O N D
LEGEND
50 FT. DEPTH
O - 66
▲ - 68
+ - 69
WATER TEMPERATURE (C)
6.00
15.00
25.00
35.00
J F M A M J J A S O N D
LEGEND
0 FT. DEPTH
O - 66
▲ - 68
+ - 69
WATER TEMPERATURE (C)
6.00
13.00
21.00
29.00
J F M A M J J A S O N D
LEGEND
110 FT. DEPTH
O - 66
▲ - 68
+ - 69
WATER TEMPERATURE (C)
6.00
13.00
21.00
29.00
J F M A M J J A S O N D
LEGEND
80 FT. DEPTH
O - 66
▲ - 68
+ - 69
WATER TEMPERATURE (C)
6.00
13.00
21.00
29.00
J F M A M J J A S O N D
LEGEND
10 FT. DEPTH
O - 66
▲ - 68
+ - 69
WATER TEMPERATURE (C)
6.00
13.00
21.00
29.00
J
WATER TEMPERATURE (C)
6.00
13.00
21.00
29.00
J
WATER TEMPERATURE (C)
6.00
13.00
21.00
29.00
J

LEGEND
10 FT. DEPTH
O - 68
▲ - 68
+ - 69
S O N D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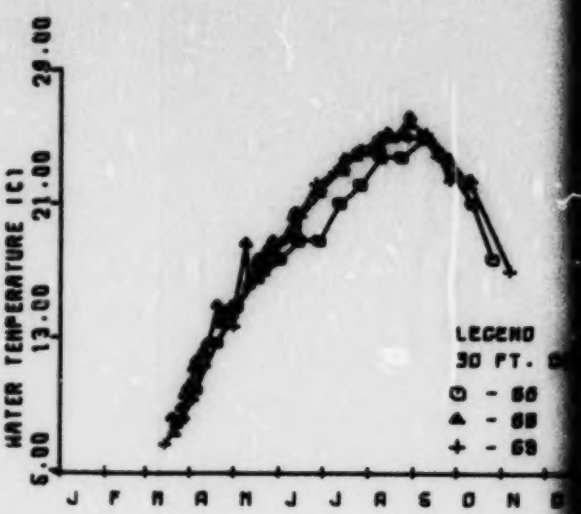
J F M A M J J A S O N D
LEGEND
20 FT. DEPTH
O - 68
▲ - 68
+ - 69


WATER TEMPERATURE (C)
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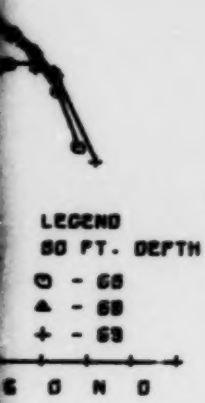
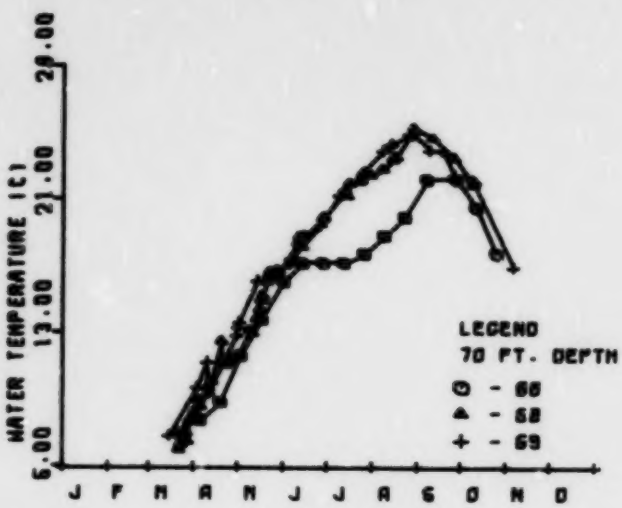
21.00
29.00
J F M A M J J A S O N D
LEGEND
30 FT.
O - 68
▲ - 68
+ - 69


LEGEND
80 FT. DEPTH
O - 68
▲ - 68
+ - 69
S O N D


WATER TEMPERATURE (C)
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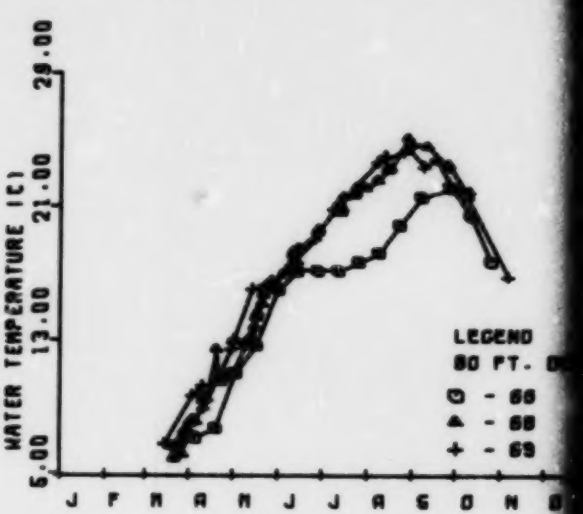
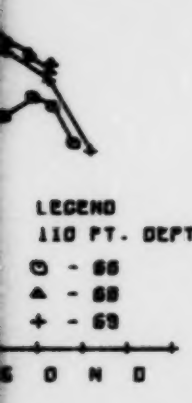
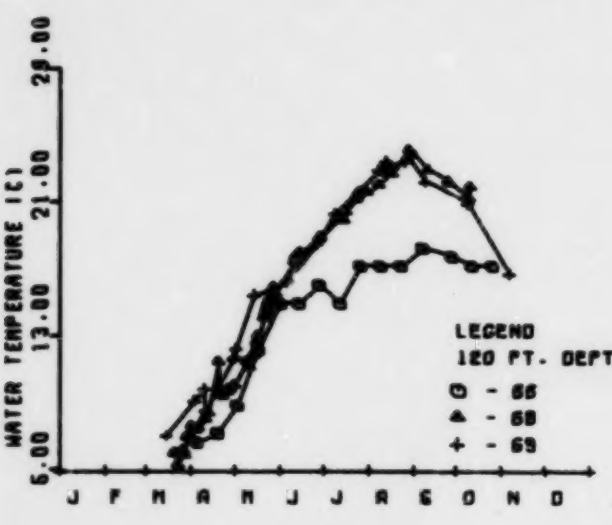
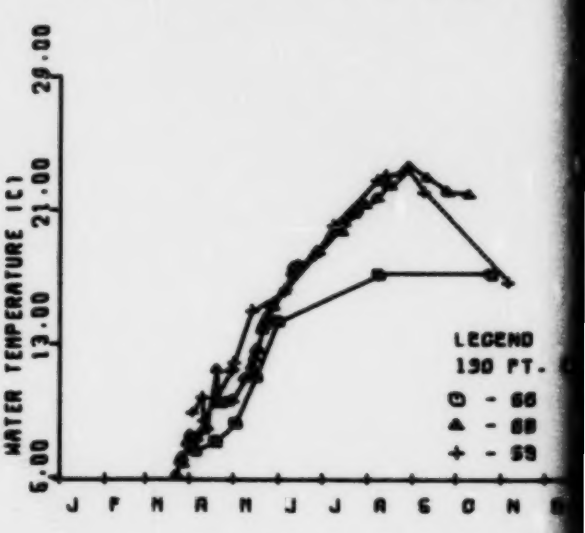
21.00
29.00
J F M A M J J A S O N D
LEGEND
70 FT. DEPTH
O - 68
▲ - 68
+ - 69


WATER TEMPERATURE (C)
5.00
13.00
21.00
29.00
J F M A M J J A S O N D
LEGEND
80 FT.
O - 68
▲ - 68
+ - 69


LEGEND
110 FT. DEPTH
O - 68
▲ - 68
+ - 69
S O N D


WATER TEMPERATURE (C)
5.00
13.00
21.00
29.00
J F M A M J J A S O N D
LEGEND
120 FT. DEPTH
O - 68
▲ - 68
+ - 69


WATER TEMPERATURE (C)
5.00
13.00
21.00
29.00
J F M A M J J A S O N D
LEGEND
130 FT.
O - 68
▲ - 68
+ - 69

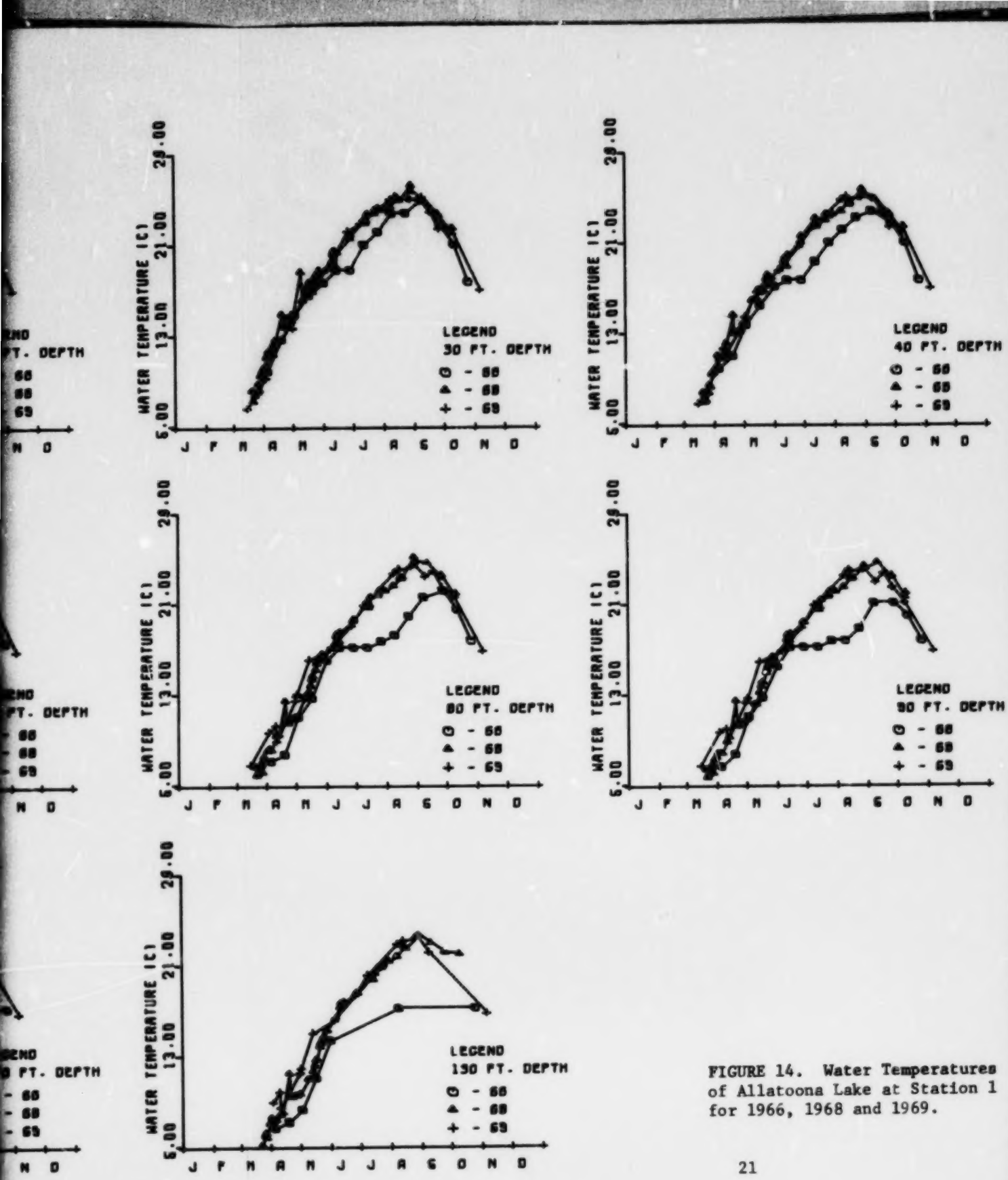
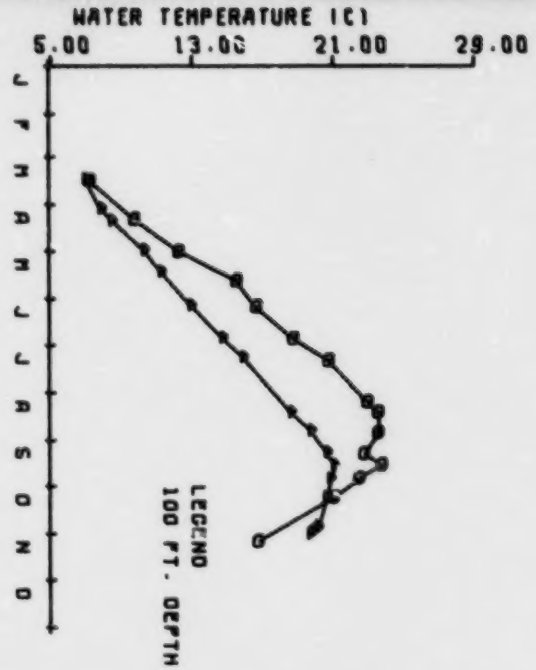


FIGURE 14. Water Temperatures of Allatoona Lake at Station 1 for 1966, 1968 and 1969.


WATER TEMPERATURE (C)
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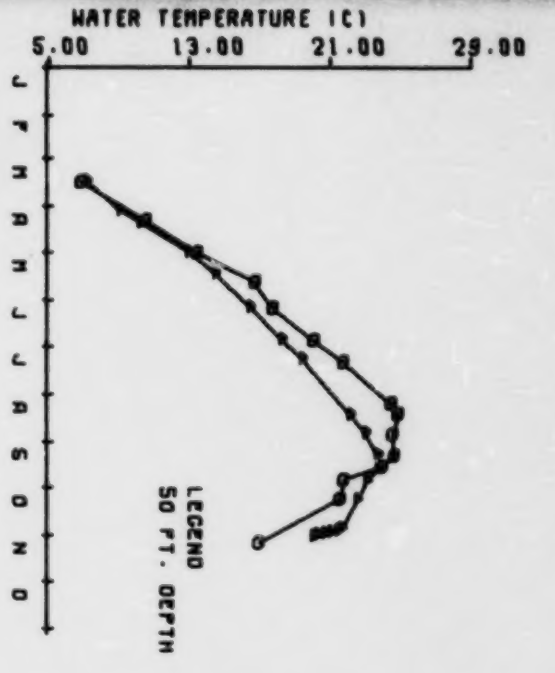
13.00
21.00
29.00
J F M A M J J A S O N D
LEGEND
100 FT. DEPTH


WATER TEMPERATURE (C)
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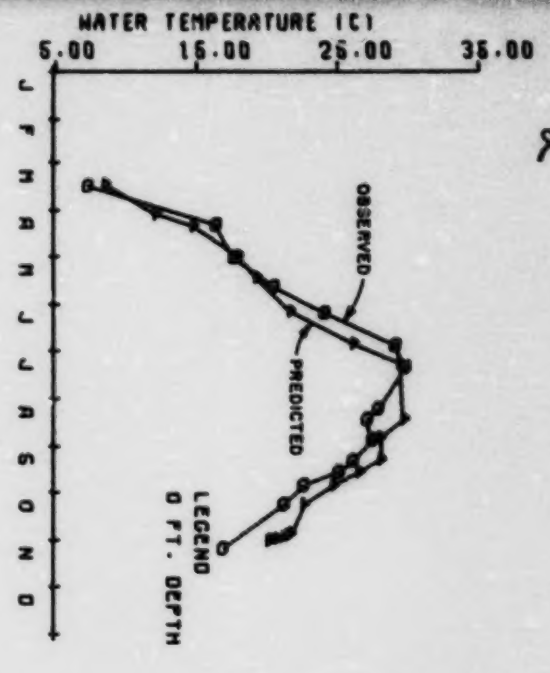
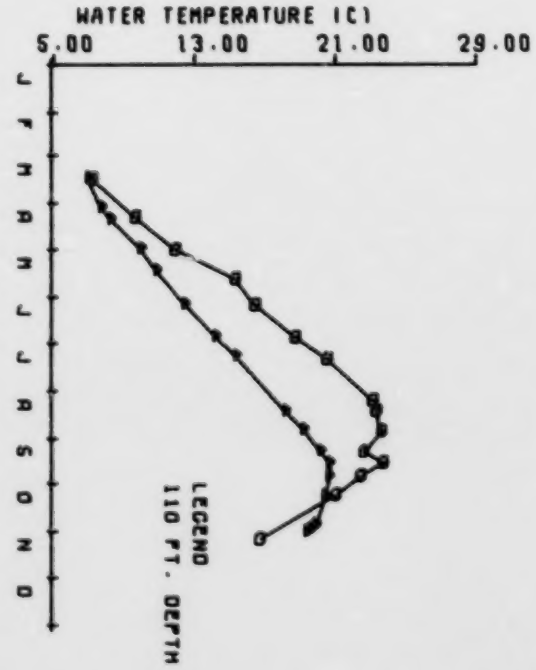
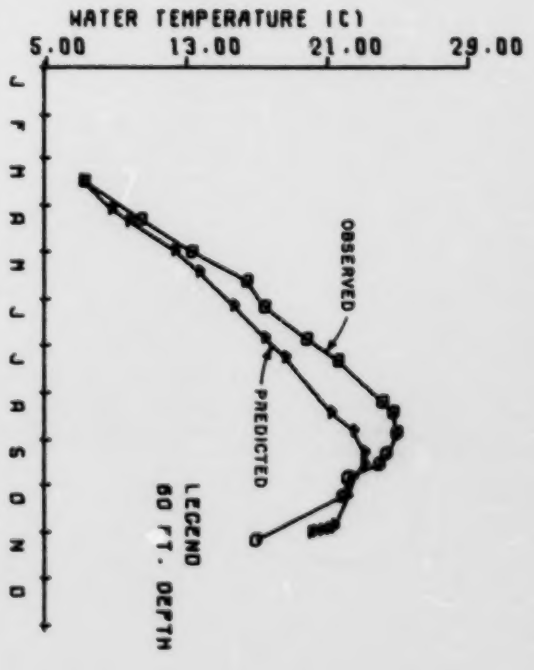
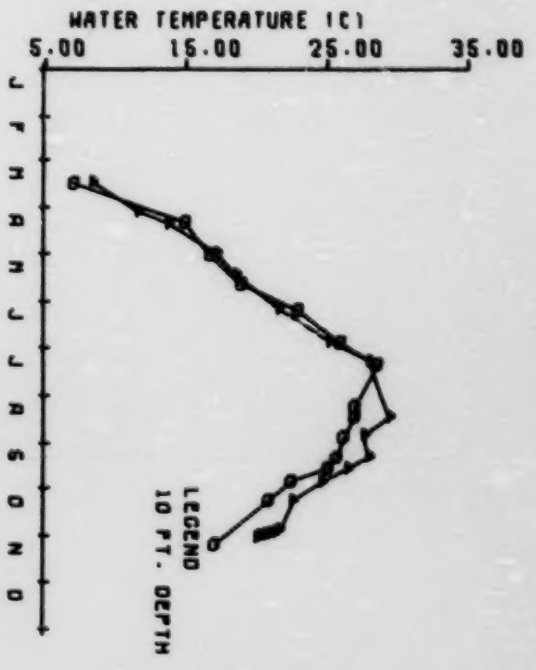
13.00
21.00
29.00
J F M A M J J A S O N D
LEGEND
50 FT. DEPTH


WATER TEMPERATURE (C)
5.00
15.00
25.00
35.00
J F M A M J J A S O N D
OBSERVED
PREDICTED
LEGEND
0 FT. DEPTH


WATER TEMPERATURE (C)
5.00
13.00
21.00
29.00
J F M A M J J A S O N D
LEGEND
110 FT. DEPTH


WATER TEMPERATURE (C)
5.00
13.00
21.00
29.00
J F M A M J J A S O N D
OBSERVED
PREDICTED
LEGEND
60 FT. DEPTH


WATER TEMPERATURE (C)
5.00
15.00
25.00
35.00
J F M A M J J A S O N D
LEGEND
10 FT. DEPTH

WATER TEMPERATURE (C)
5.00
13.00
21.00
29.00

WATER TEMPERATURE (C)
5.00
13.00
21.00
29.00

WATER TEMPERATURE (C)
5.00
13.00
21.00
29.00

WATER TEMPERATURE (C)
5.00
13.00
21.00
29.00
J F M A M J J A S O N D
LEGEND
20 FT. DEPTH

WATER TEMPERATURE (C)
5.00
13.00
21.00
29.00
J F M A M J J A S O N D
OBSERVED
PREDICTED
LEGEND
30 FT. DEPTH

WATER TEMPERATURE (C)
5.00
13.00
21.00
29.00

WATER TEMPERATURE (C)
5.00
13.00
21.00
29.00
J F M A M J J A S O N D
LEGEND
70 FT. DEPTH

WATER TEMPERATURE (C)
5.00
13.00
21.00
29.00
J F M A M J J A S O N D
LEGEND
80 FT. DEPTH

WATER TEMPERATURE (C)
5.00
13.00
21.00
29.00

WATER TEMPERATURE (C)
5.00
13.00
21.00
29.00
J F M A M J J A S O N D
OBSERVED
PREDICTED
LEGEND
120 FT. DEPTH

WATER TEMPERATURE (C)
5.00
13.00
21.00
29.00
J F M A M J J A S O N D
LEGEND
130 FT. DEPTH

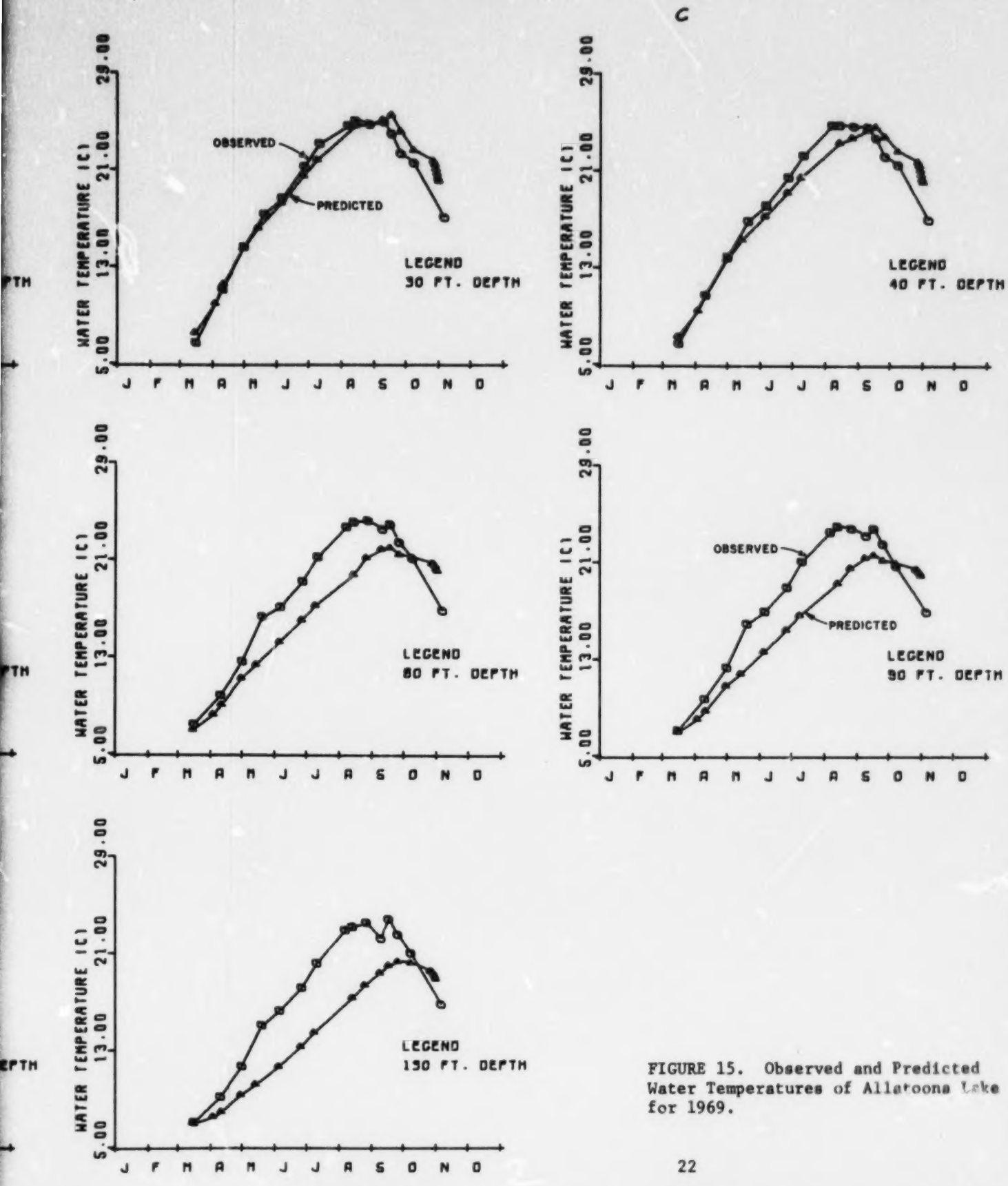
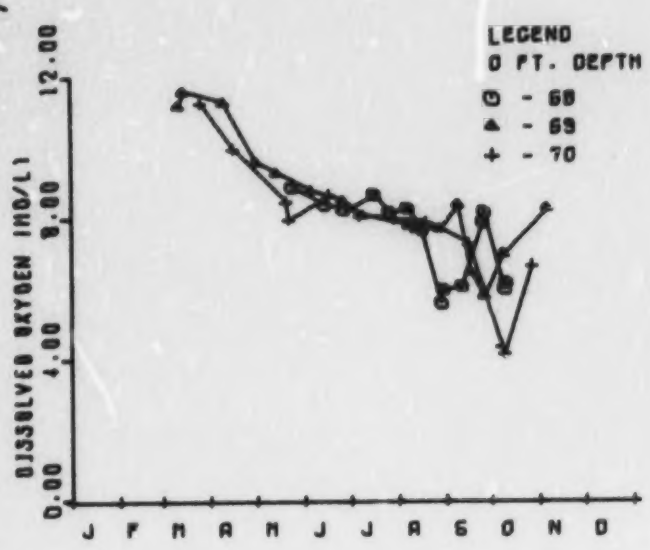
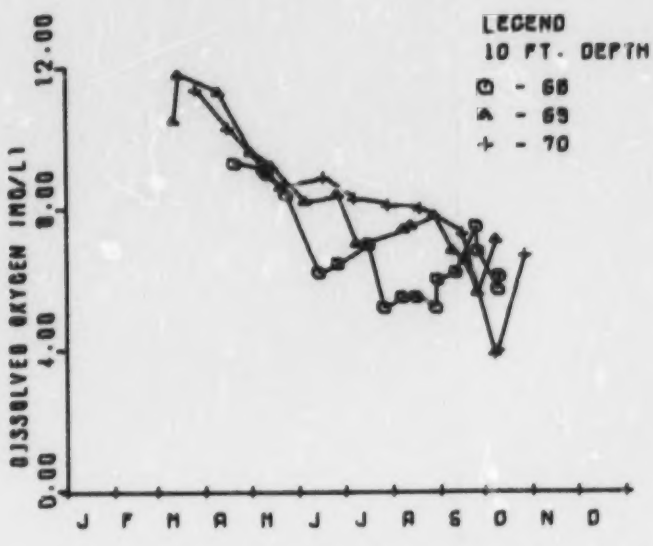
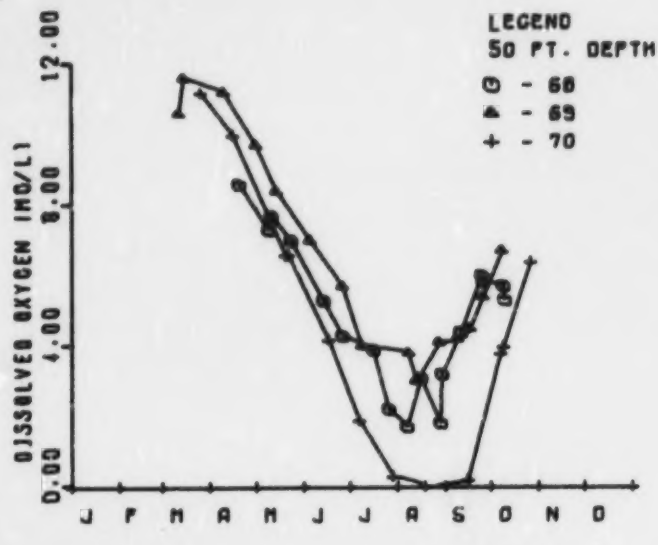
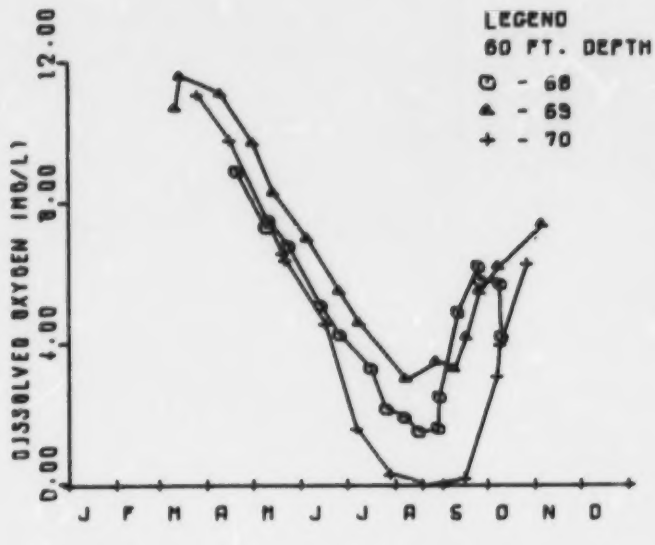


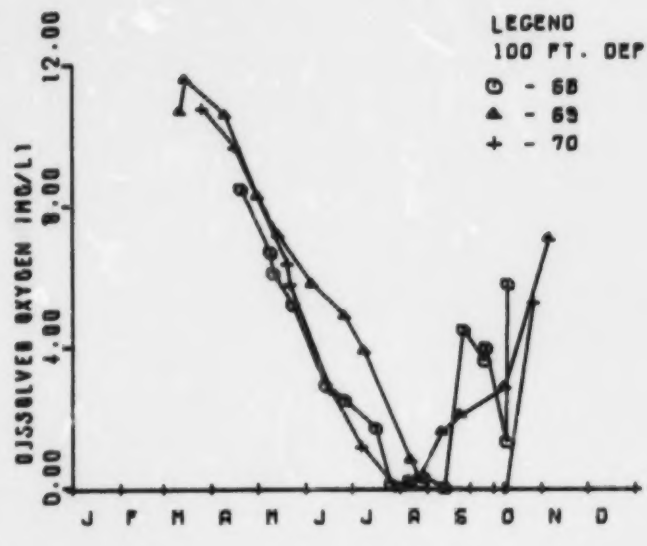
FIGURE 15. Observed and Predicted Water Temperatures of Allaroona Lake for 1969.

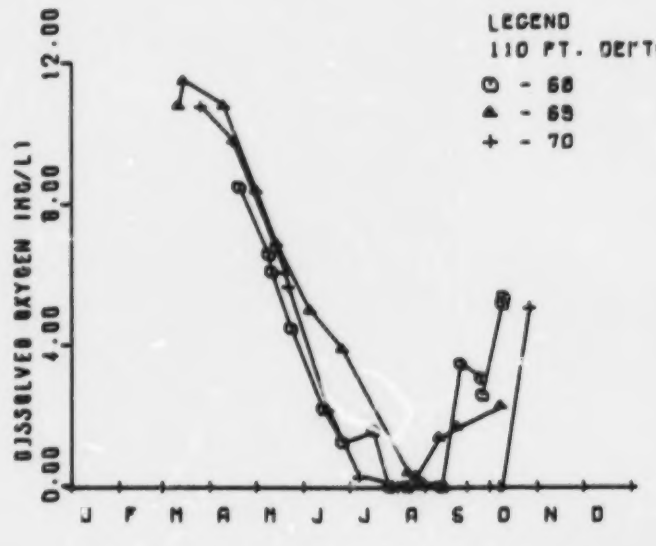

LEGEND
0 FT. DEPTH
68
69
70
DISSOLVED OXYGEN (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N D


LEGEND
10 FT. DEPTH
68
69
70
DISSOLVED OXYGEN (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N D

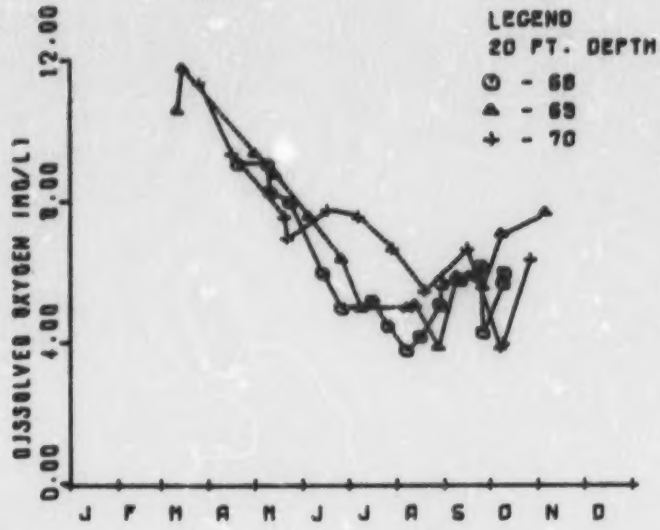

LEGEND
50 FT. DEPTH
68
69
70
DISSOLVED OXYGEN (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N D

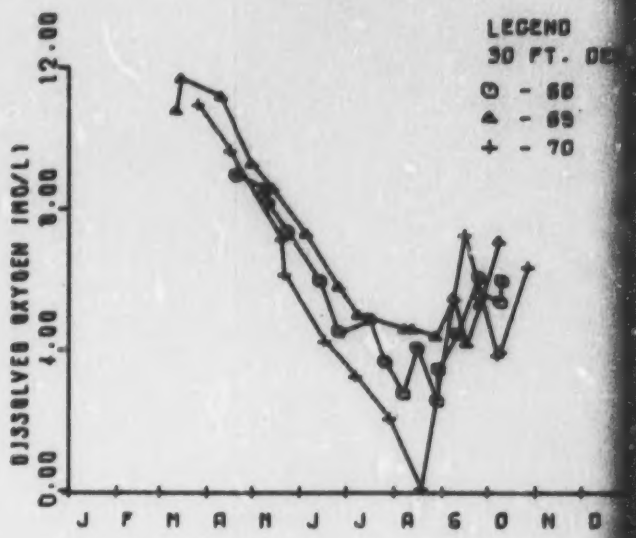

LEGEND
60 FT. DEPTH
68
69
70
DISSOLVED OXYGEN (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N D


LEGEND
100 FT. DEPTH
68
69
70
DISSOLVED OXYGEN (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N D

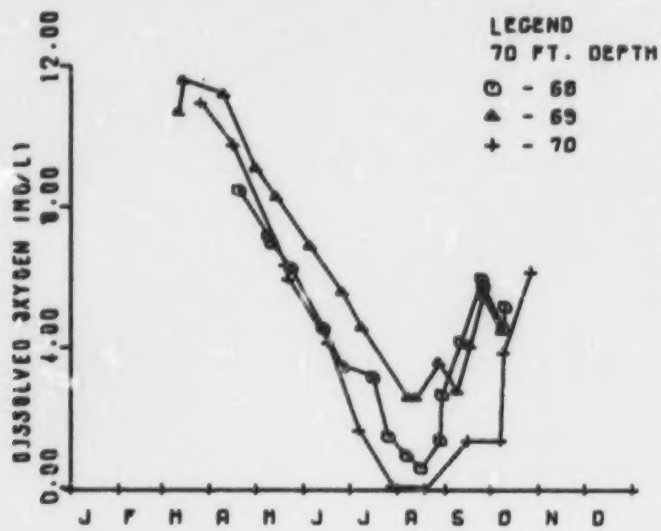

LEGEND
110 FT. DEPTH
68
69
70
DISSOLVED OXYGEN (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N D

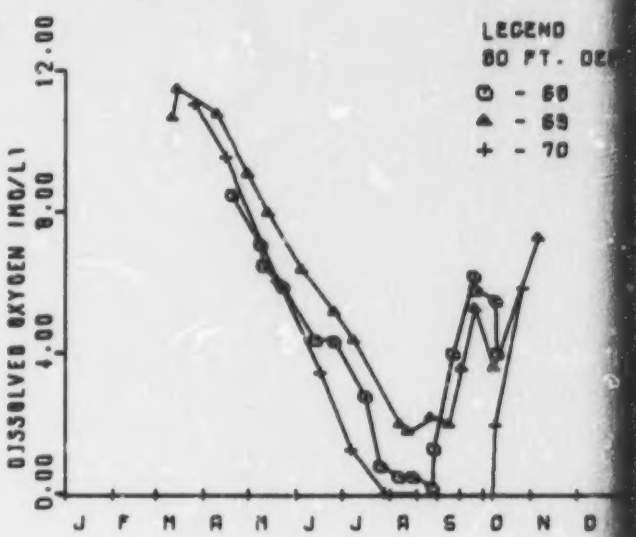
END
FT. DEPTH
68
69
70
N D


LEGEND
20 FT. DEPTH
68
69
70
DISSOLVED OXYGEN (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N D

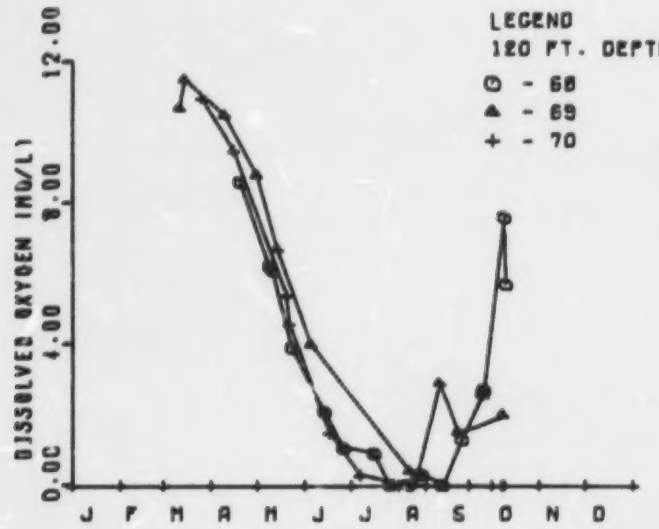

LEGEND
30 FT. DE
68
69
70
DISSOLVED OXYGEN (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N D

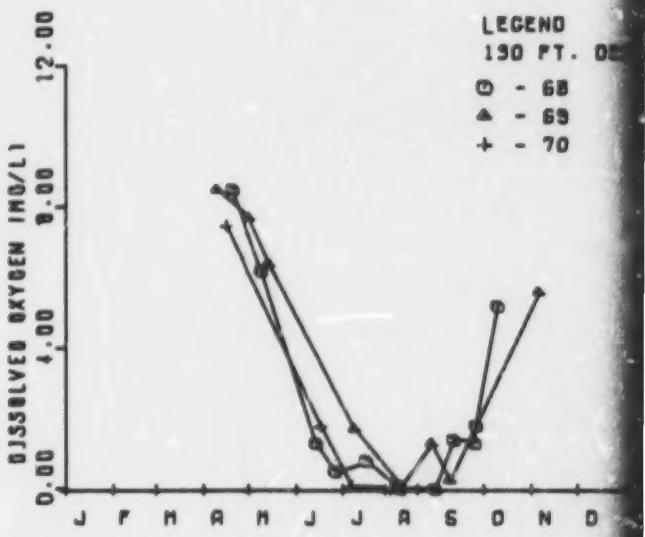
END
FT. DEPTH
68
69
70
N D

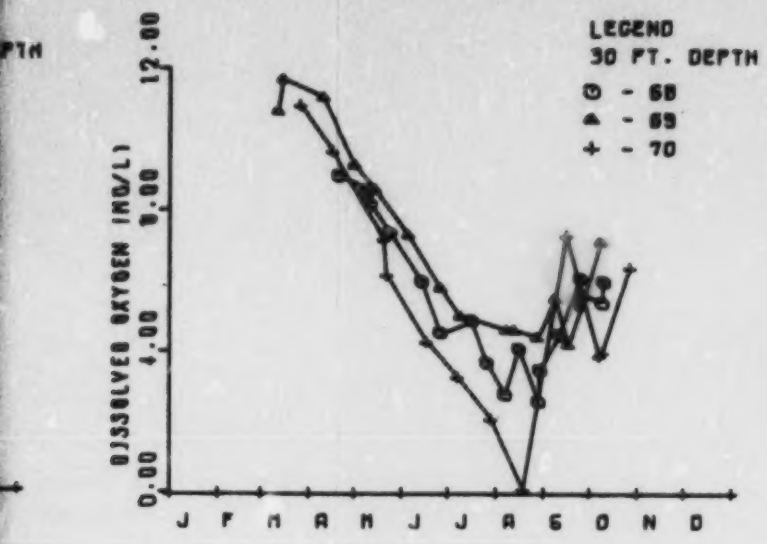

LEGEND
70 FT. DEPTH
68
69
70
DISSOLVED OXYGEN (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N D

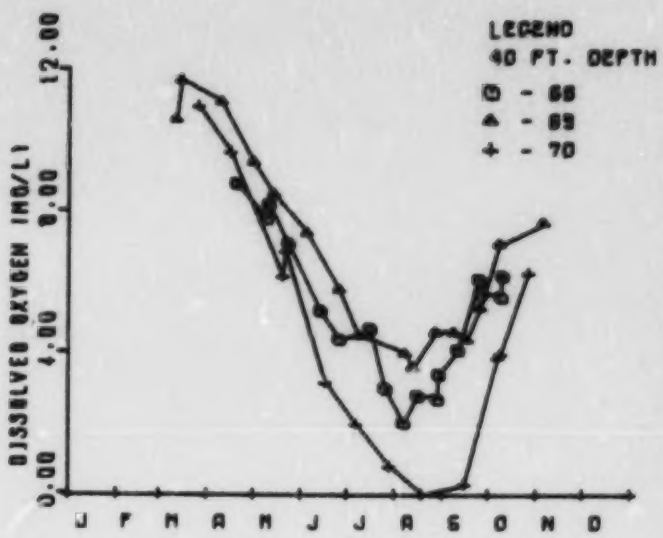

LEGEND
80 FT. DE
68
69
70
DISSOLVED OXYGEN (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N D

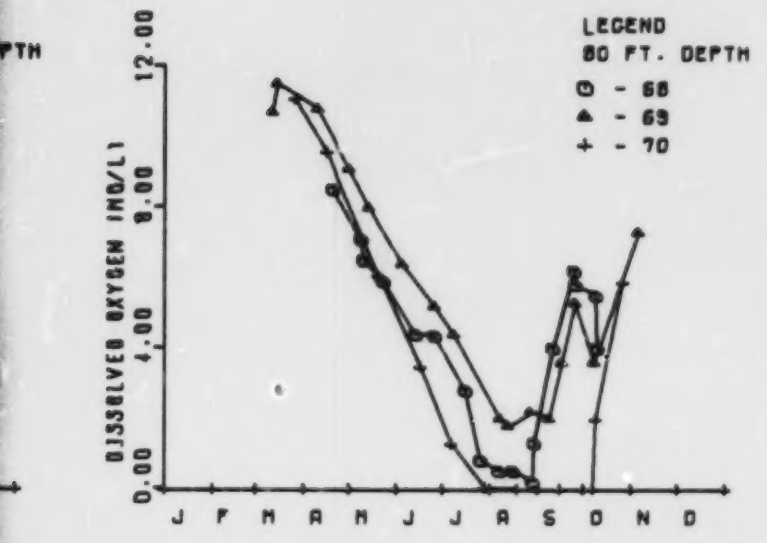
END
FT. DEPTH
68
69
70
N D

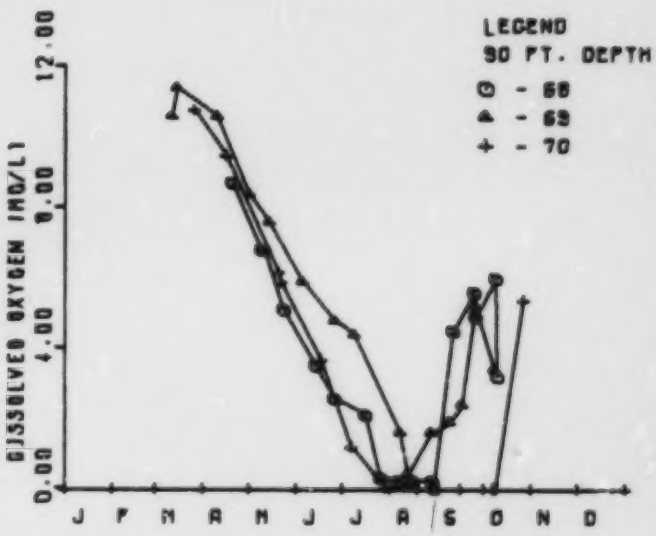

LEGEND
120 FT. DEPTH
68
69
70
DISSOLVED OXYGEN (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N D


LEGEND
130 FT. DE
68
69
70
DISSOLVED OXYGEN (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N D









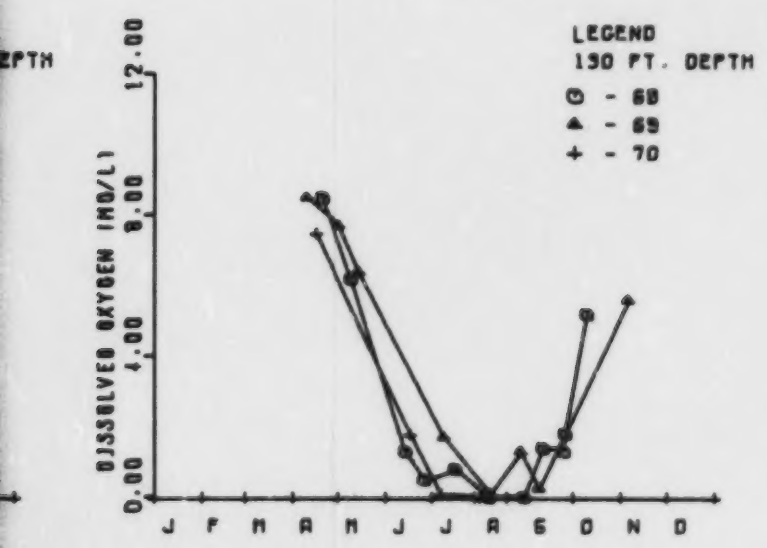


FIGURE 16. Dissolved Oxygen Concentrations of Allatoona Lake at Station 1 for 1968, 1969 and 1970.

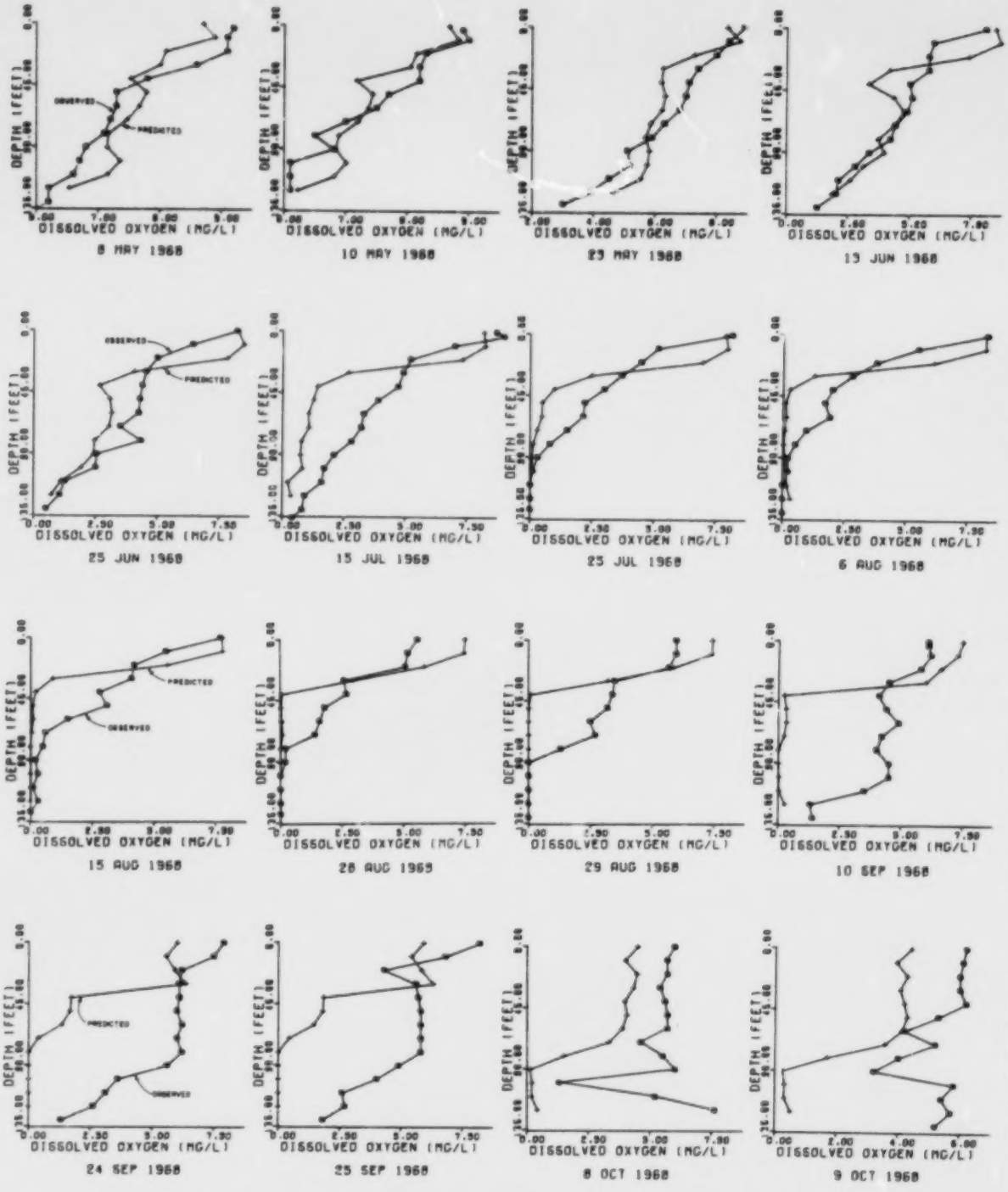


FIGURE 17. Observed and Predicted Dissolved Oxygen Concentrations of Allatoona Lake at Station 1 for 1968.

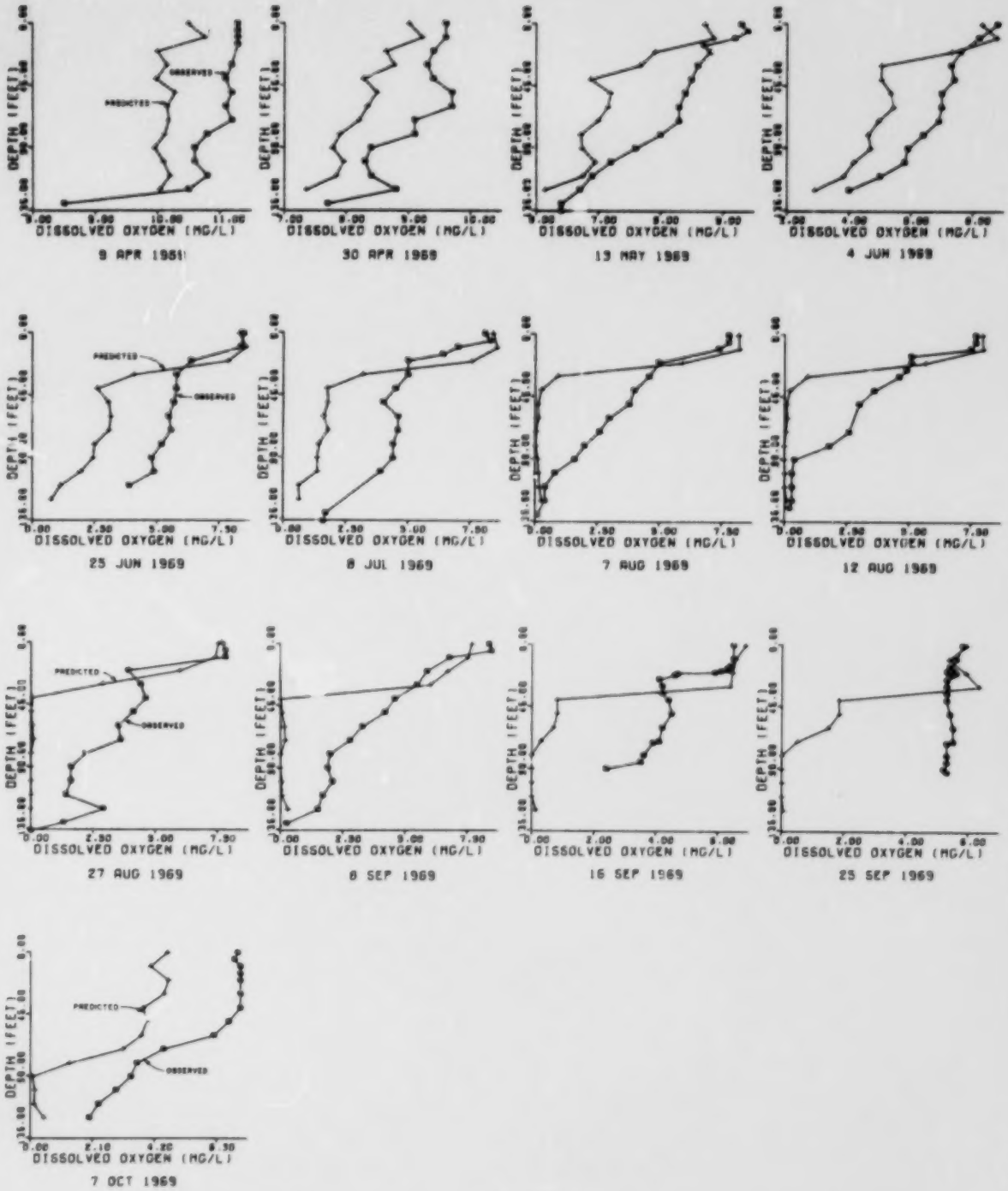


FIGURE 18. Observed and Predicted Dissolved Oxygen Concentrations of Allatoona Lake at Station 1 for 1969.

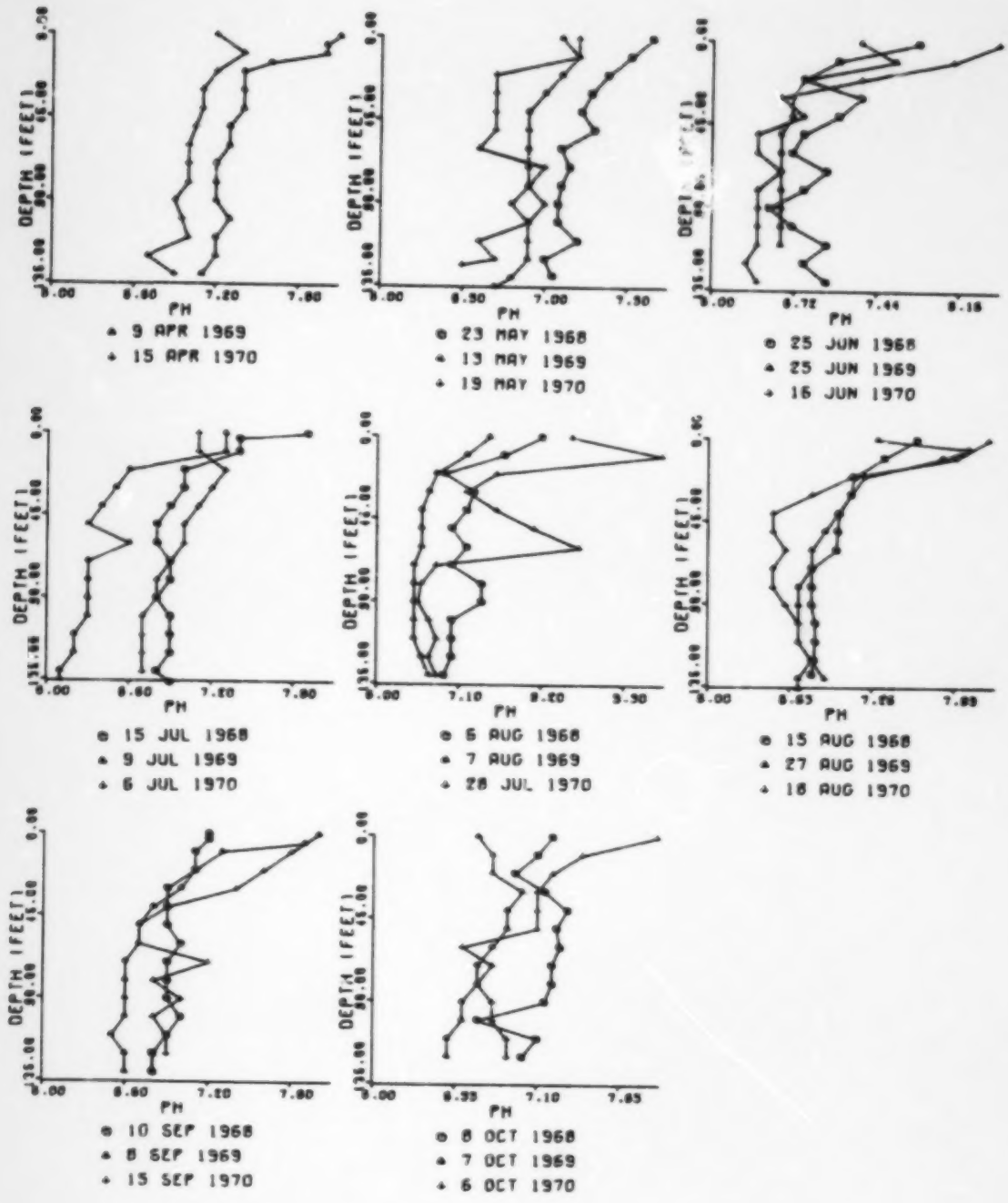


FIGURE 19. Ph of Allatoona Lake at Station 1 for 1968, 1969 and 1970.

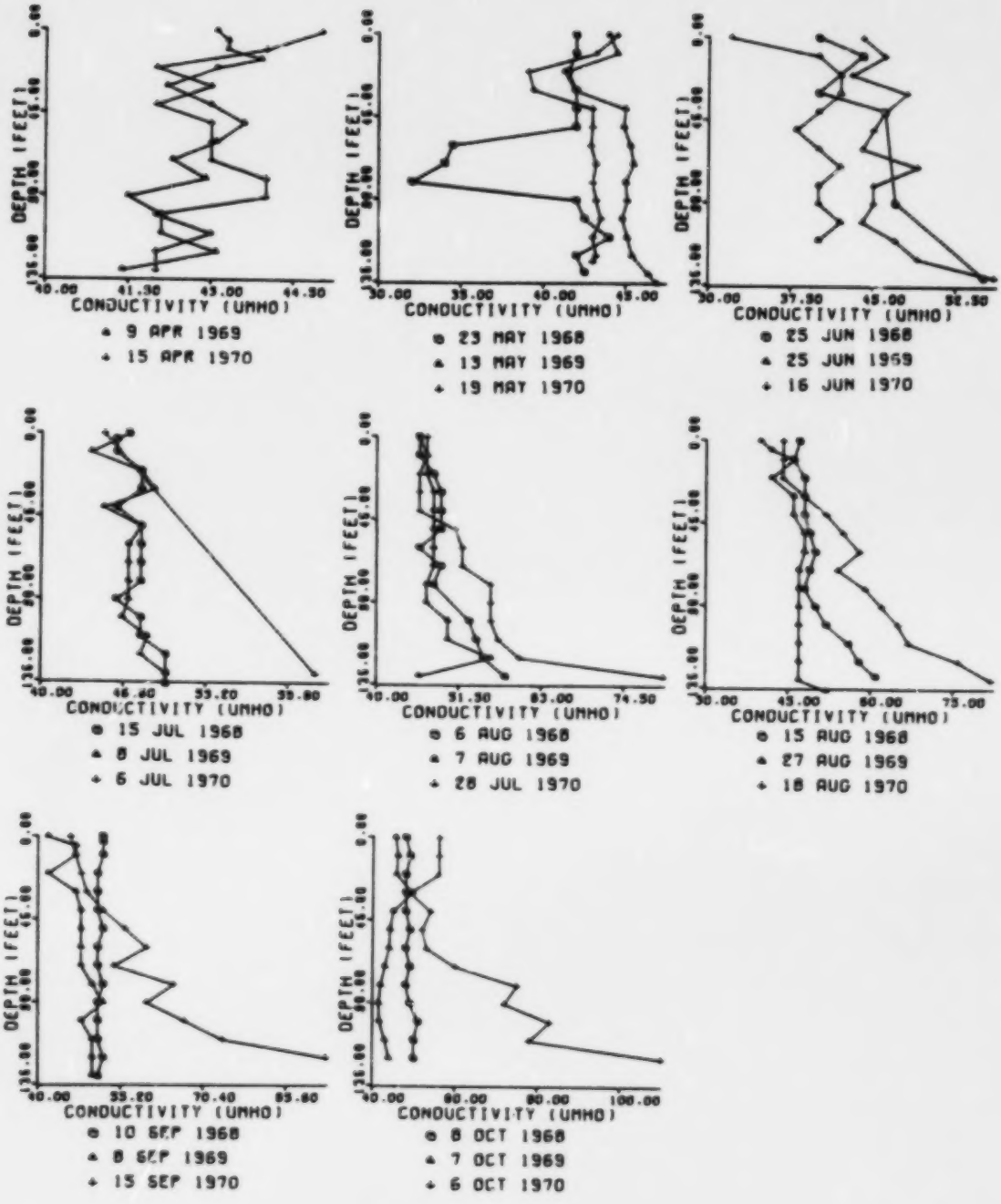


FIGURE 20. Conductivity of Allatoona Lake at Station 1 for 1968, 1969, and 1970.

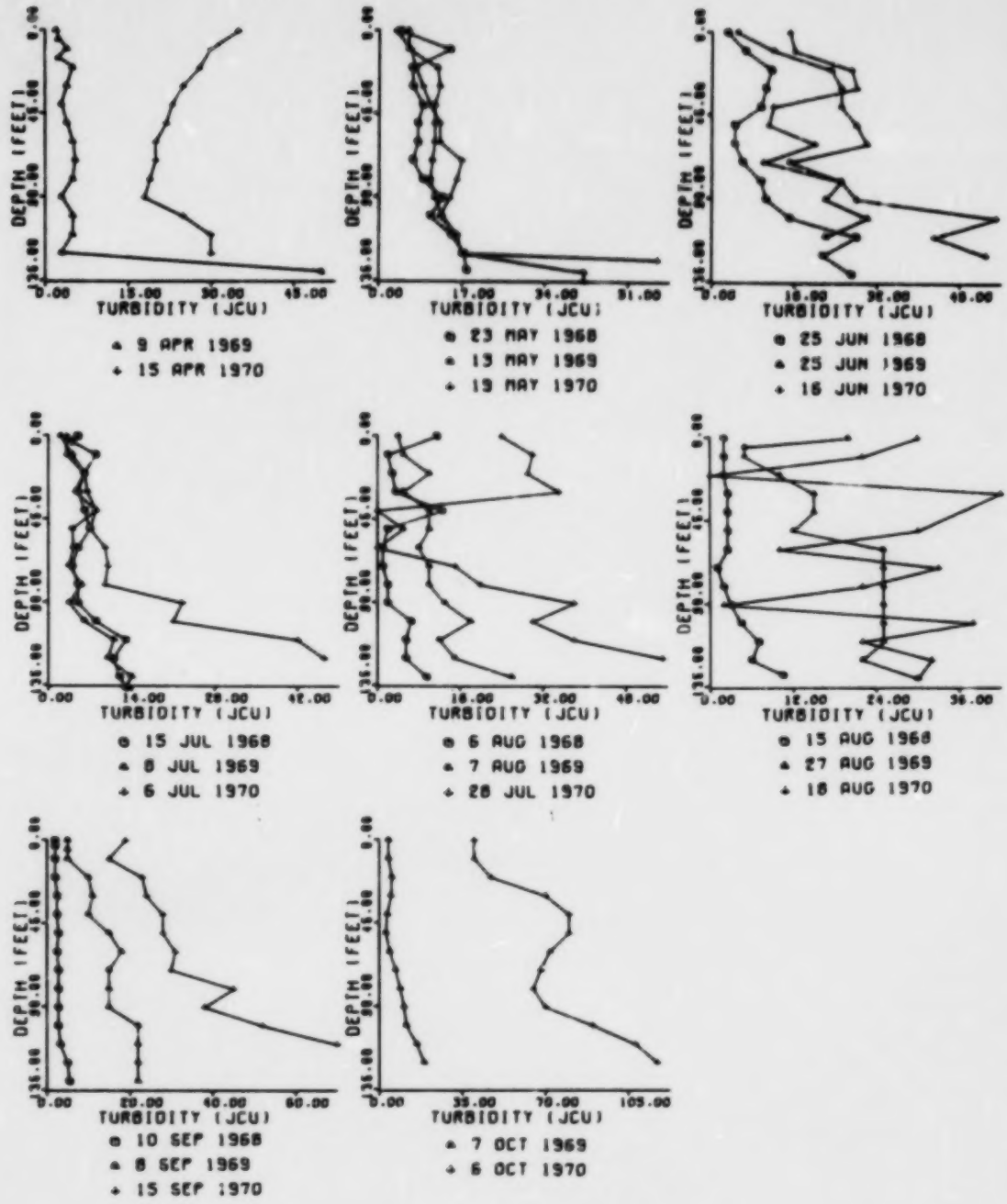
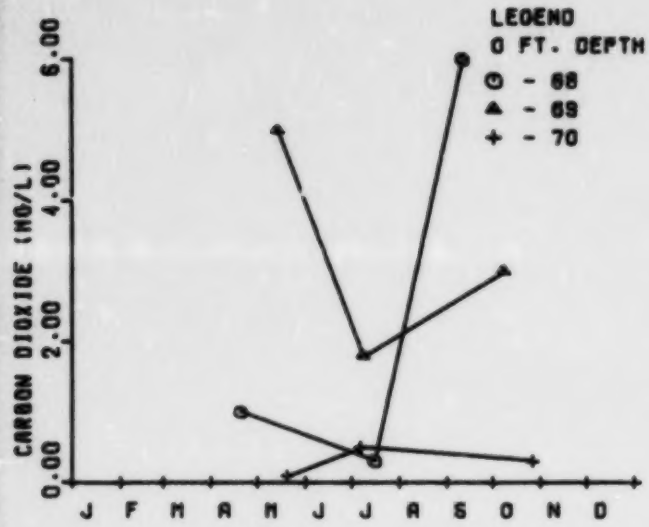
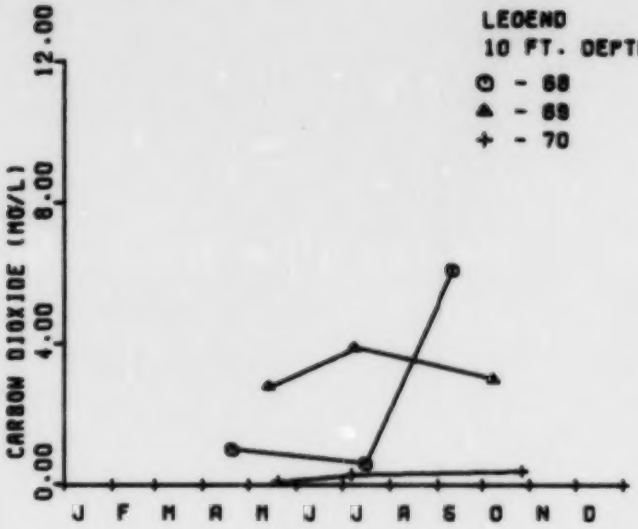
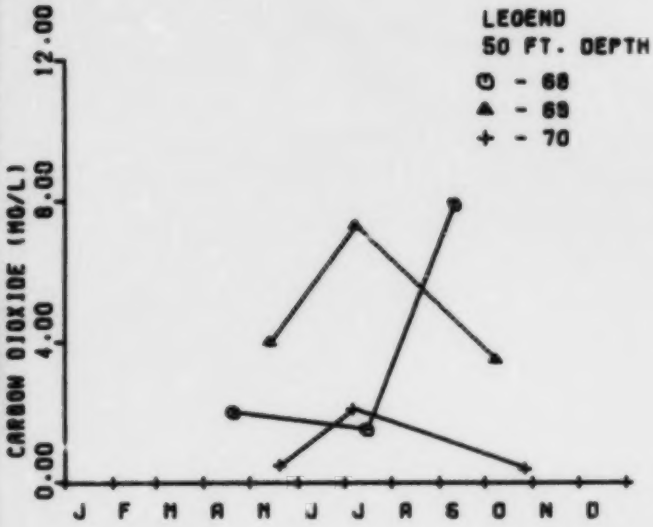
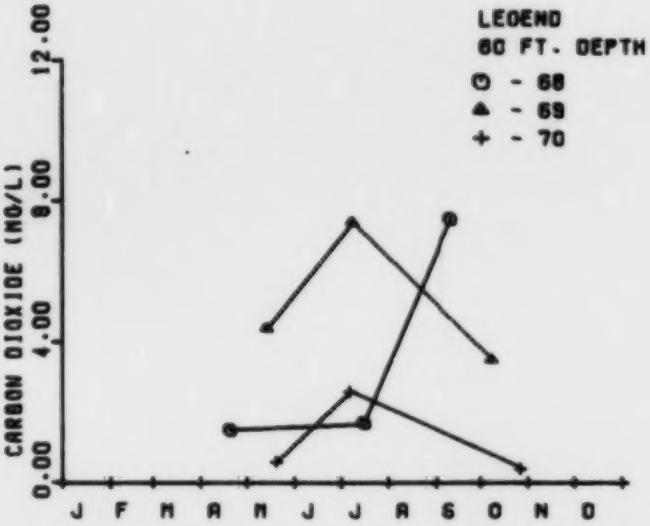


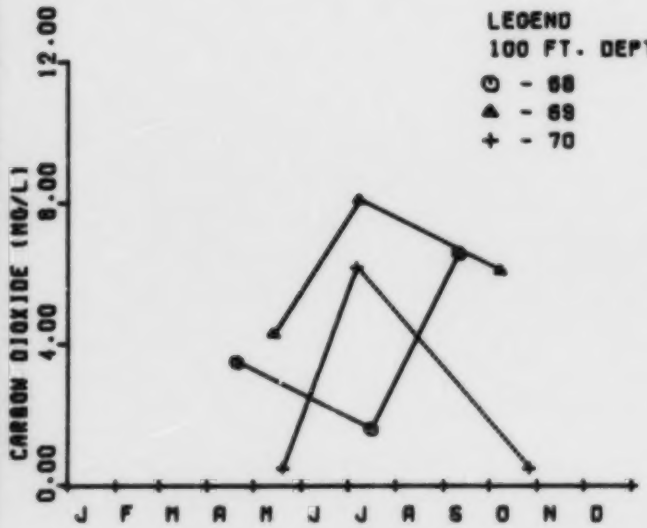
FIGURE 21. Turbidity of Allatoona Lake at Station 1 for 1968, 1969, and 1970.

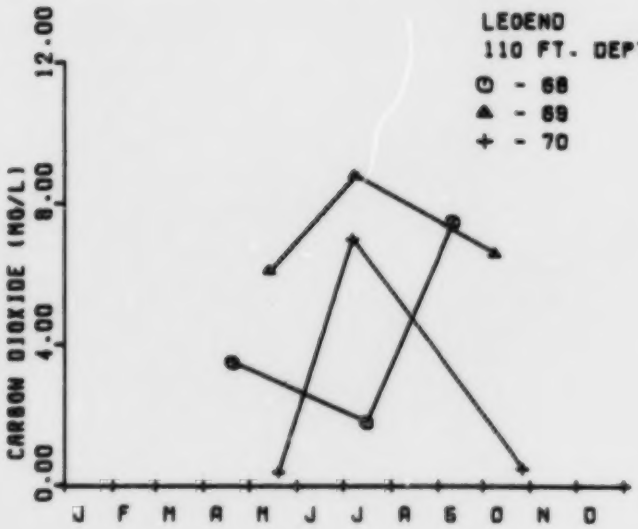

LEGEND
0 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
CARBON DIOXIDE (MG/L)
0.00
2.00
4.00
6.00
J F M A M J J A S O N D


LEGEND
10 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
CARBON DIOXIDE (MG/L)
0.00
4.00
8.00
12.00
J F M A M J J A S O N D

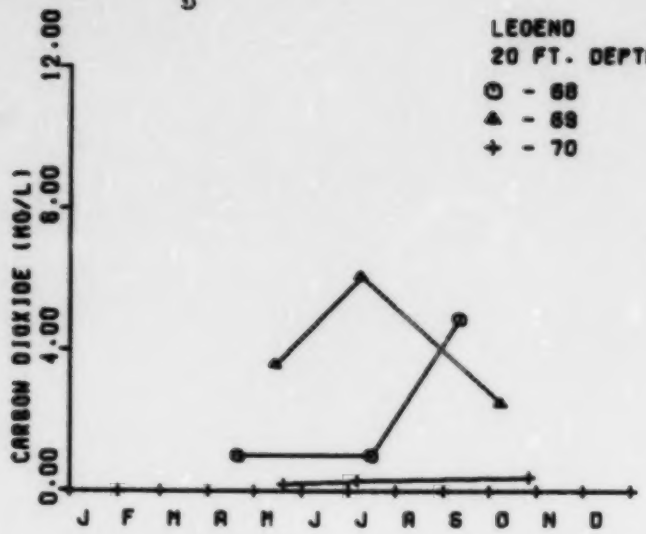

LEGEND
50 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
CARBON DIOXIDE (MG/L)
0.00
4.00
8.00
12.00
J F M A M J J A S O N D

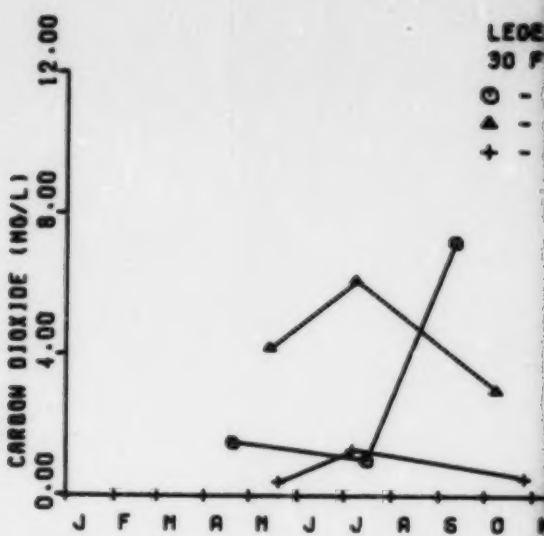

LEGEND
60 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
CARBON DIOXIDE (MG/L)
0.00
4.00
8.00
12.00
J F M A M J J A S O N D


LEGEND
100 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
CARBON DIOXIDE (MG/L)
0.00
4.00
8.00
12.00
J F M A M J J A S O N D

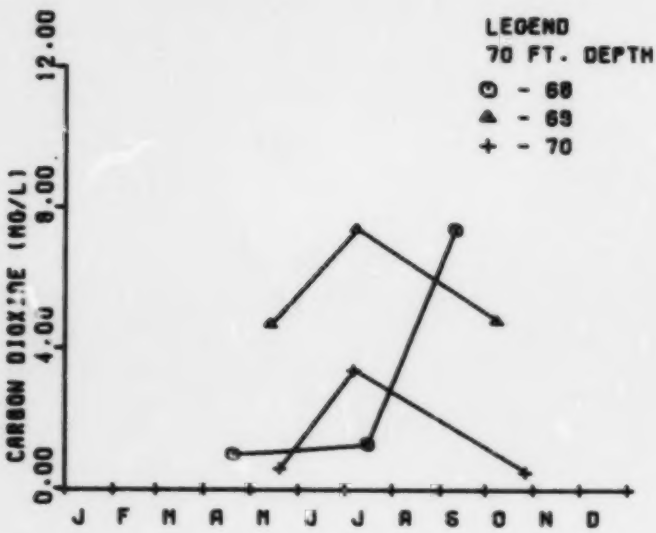

LEGEND
110 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
CARBON DIOXIDE (MG/L)
0.00
4.00
8.00
12.00
J F M A M J J A S O N D

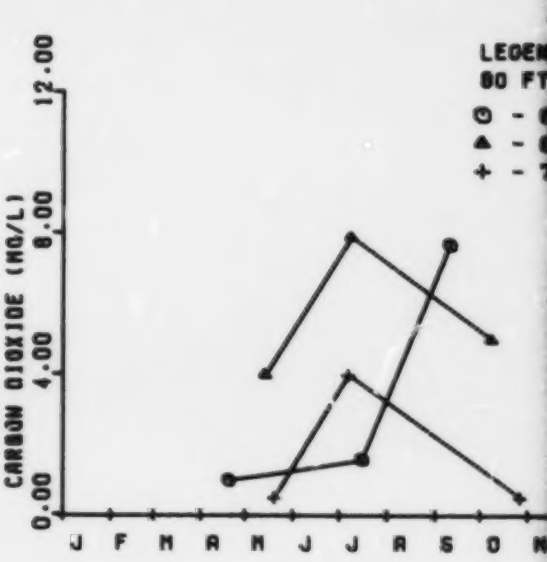
LEGEND
10 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
O N D


LEGEND
20 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
CARBON DIOXIDE (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N D

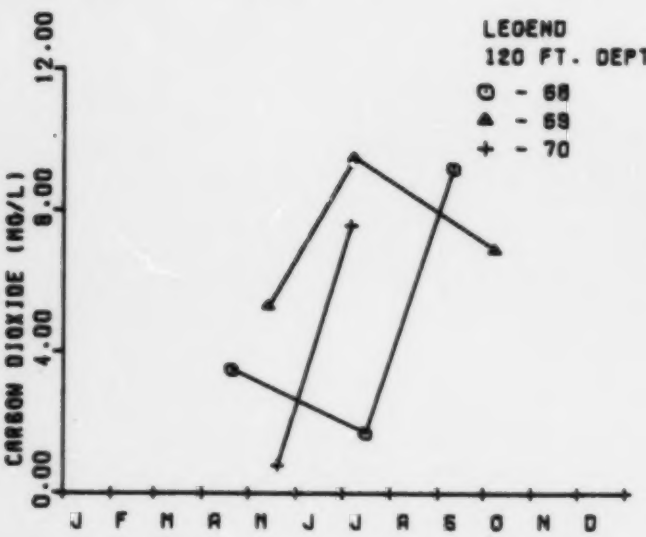

LEGE
30 F
⊙ -
▲ -
+ -
CARBON DIOXIDE (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O

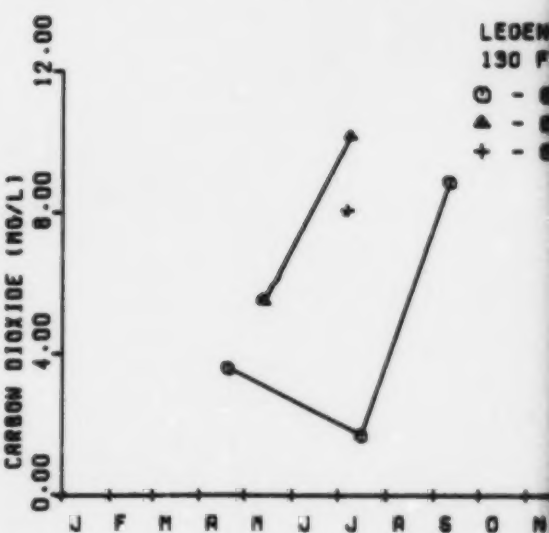
LEGEND
60 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
O N D


LEGEND
70 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
CARBON DIOXIDE (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N D


LEGEN
80 FT
⊙ -
▲ -
+ -
CARBON DIOXIDE (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N

LEGEND
110 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
O N D


LEGEND
120 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
CARBON DIOXIDE (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N D


LEGEN
130 F
⊙ -
▲ -
+ -
CARBON DIOXIDE (MG/L)
12.00
8.00
4.00
0.00
J F M A M J J A S O N

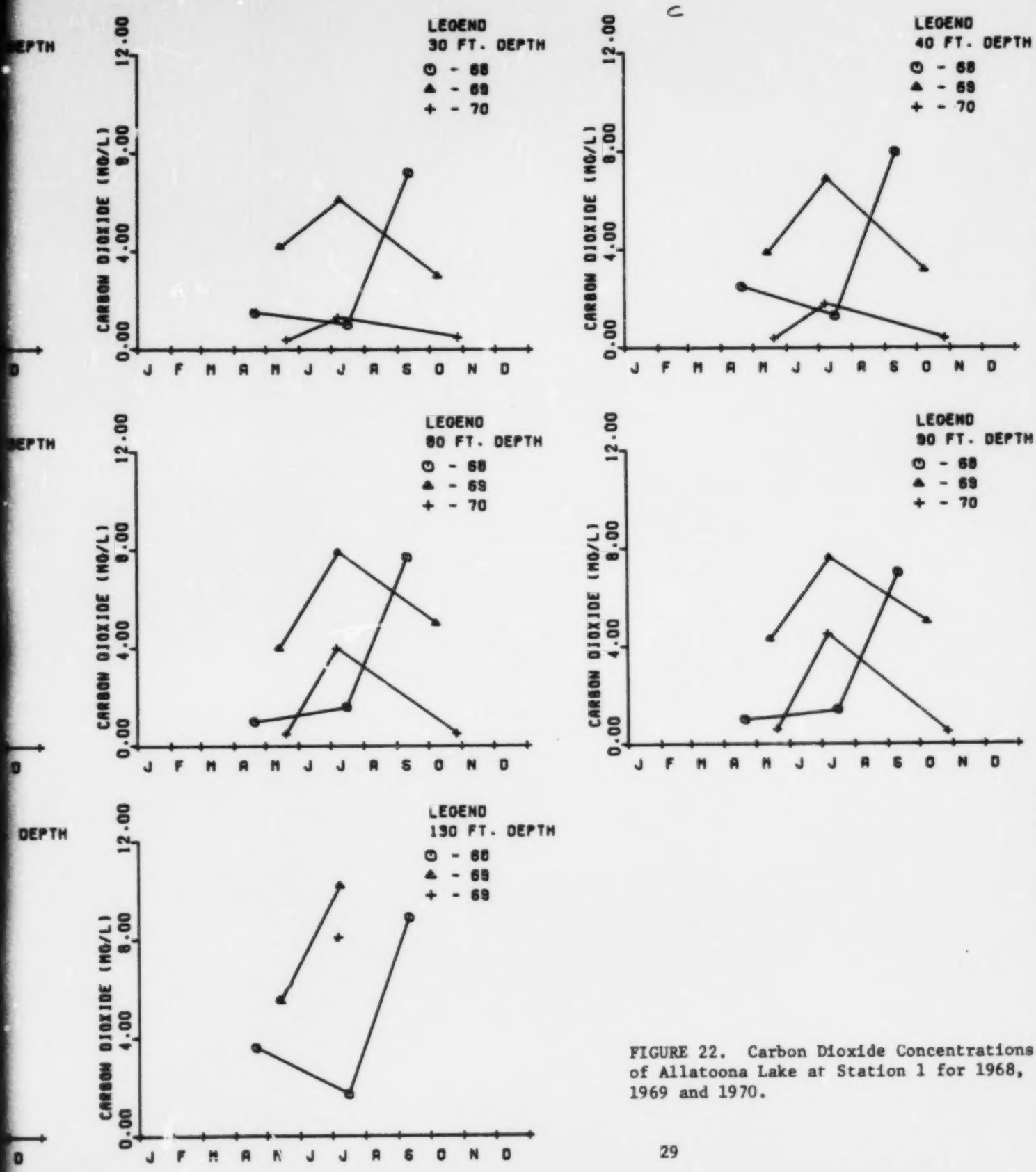


FIGURE 22. Carbon Dioxide Concentrations of Allatoona Lake at Station 1 for 1968, 1969 and 1970.

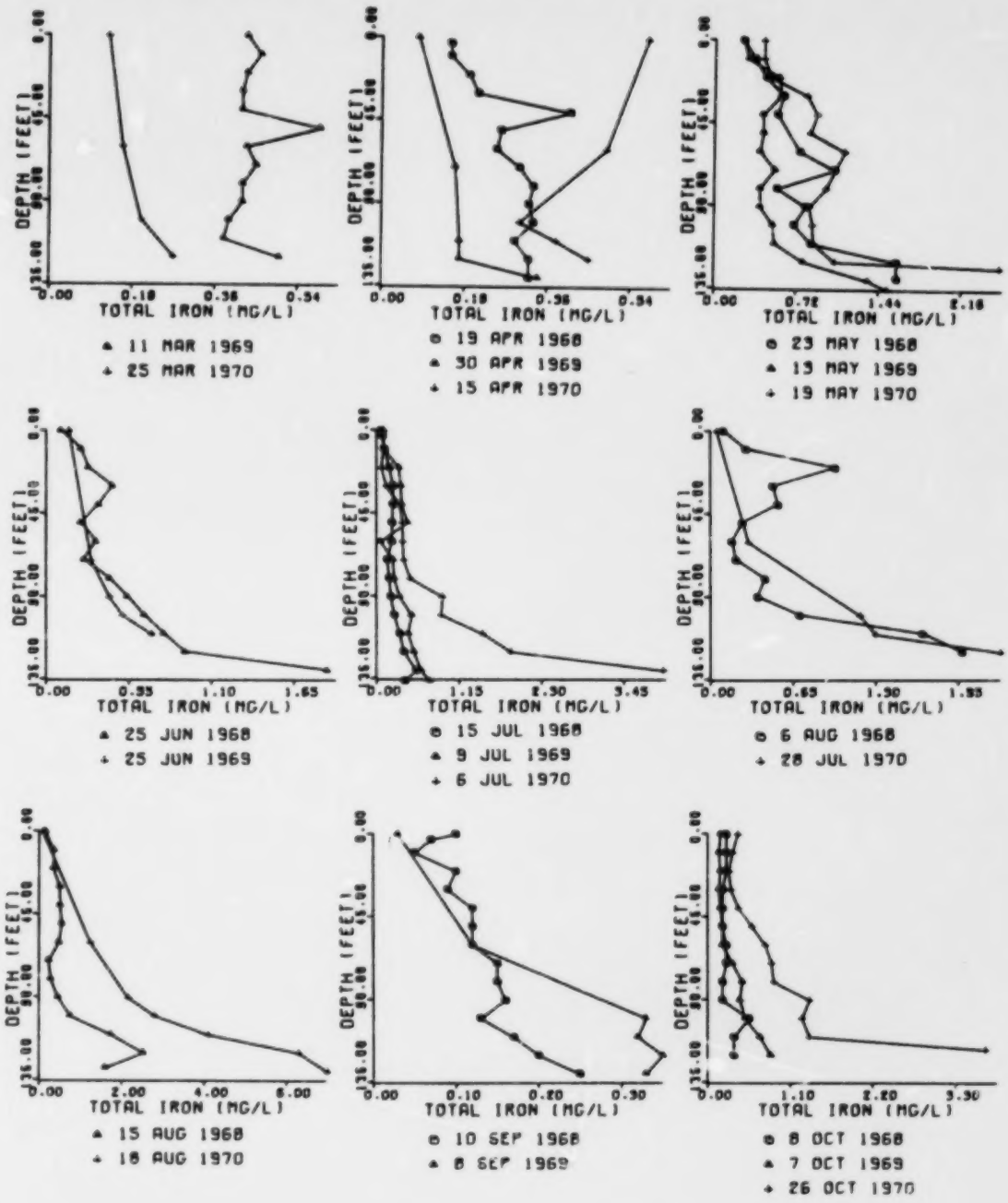


FIGURE 23. Total Iron Concentrations of Allatoona Lake at Station 1 for 1968, 1969 and 1970.

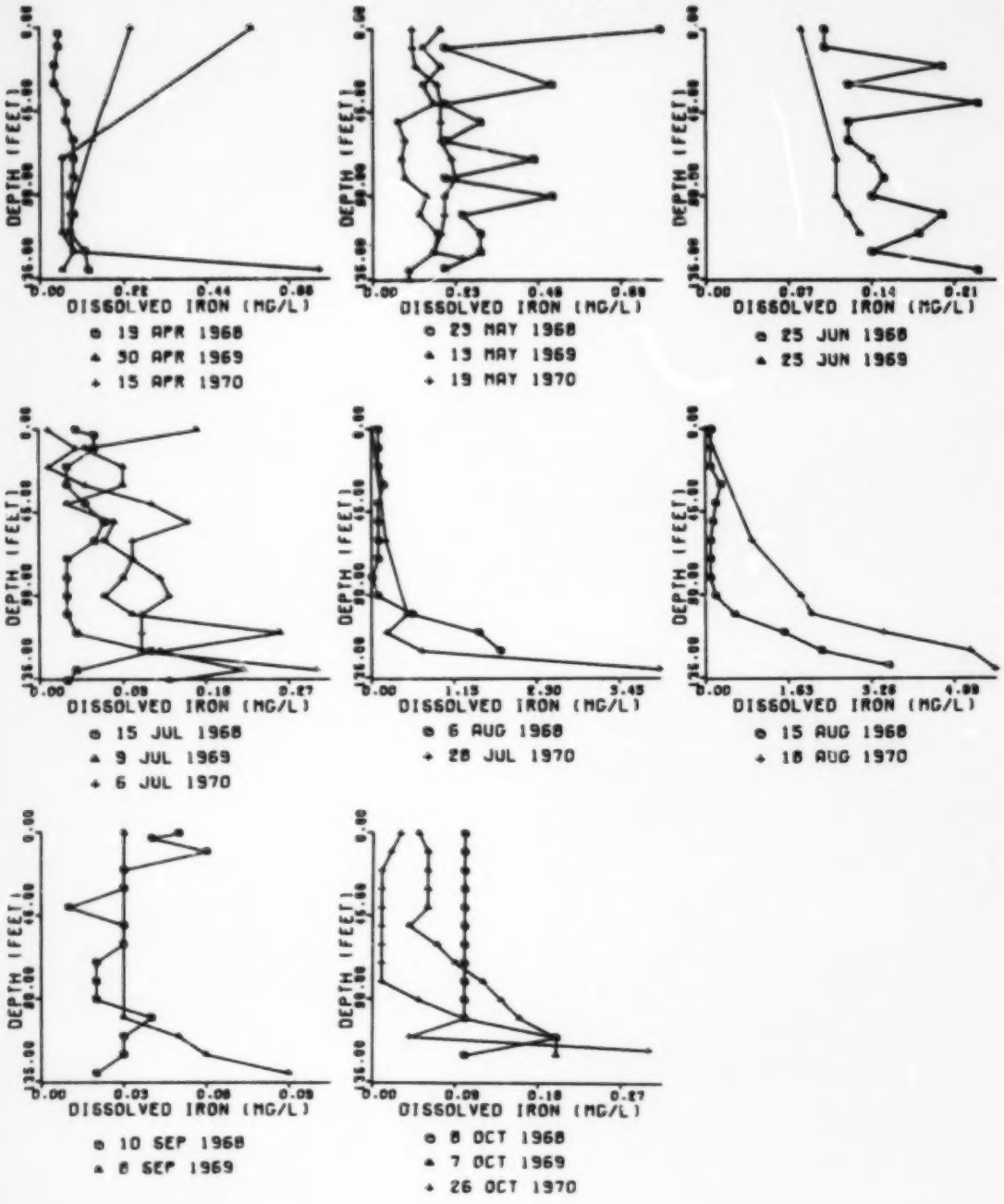


FIGURE 24. Dissolved Iron Concentrations of Allatoona Lake at Station 1 for 1968, 1969 and 1970.

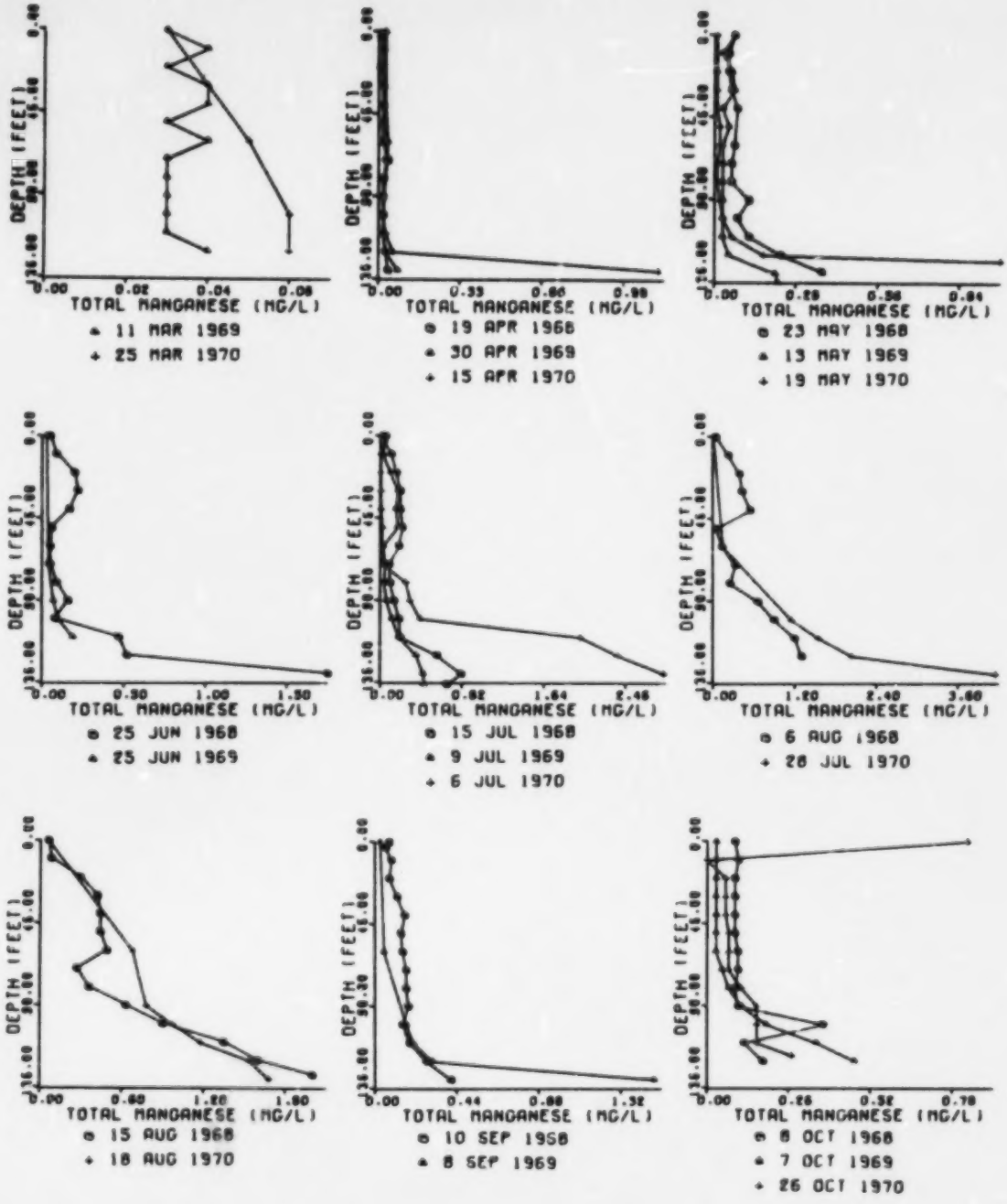


FIGURE 25. Total Manganese Concentrations of Allatoona Lake at Station 1 for 1968, 1969 and 1970.

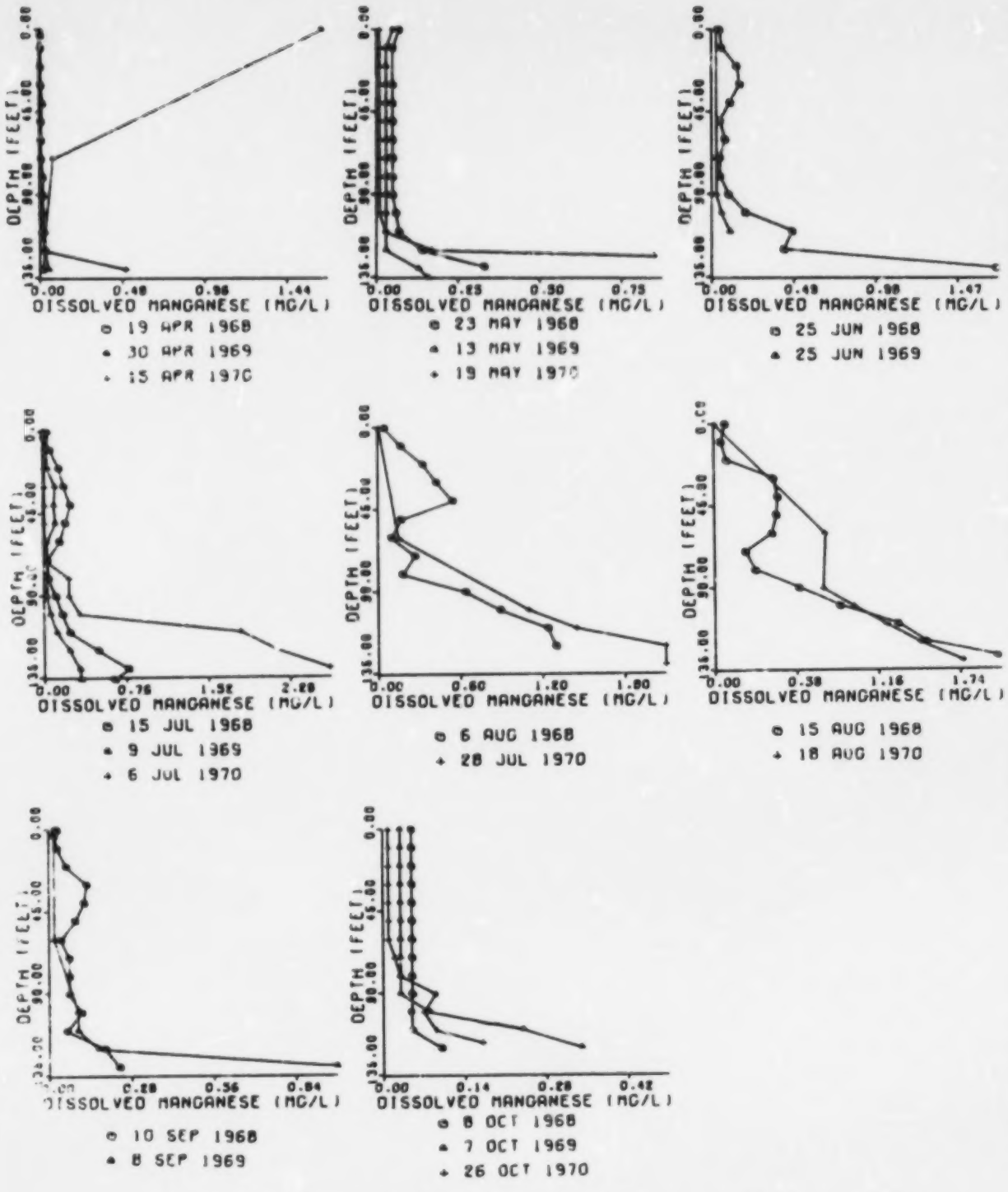
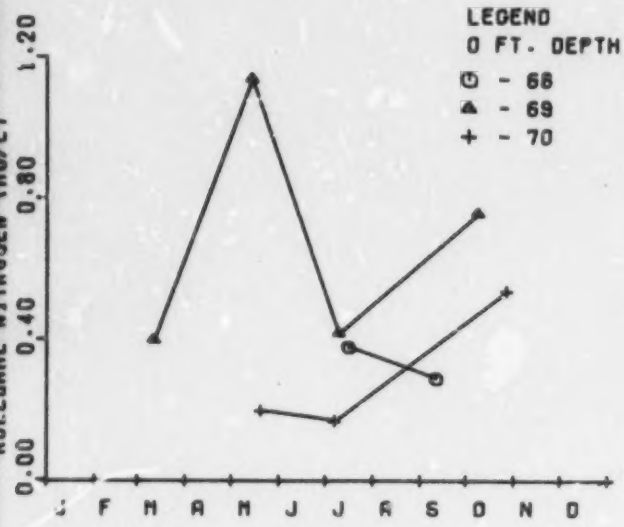
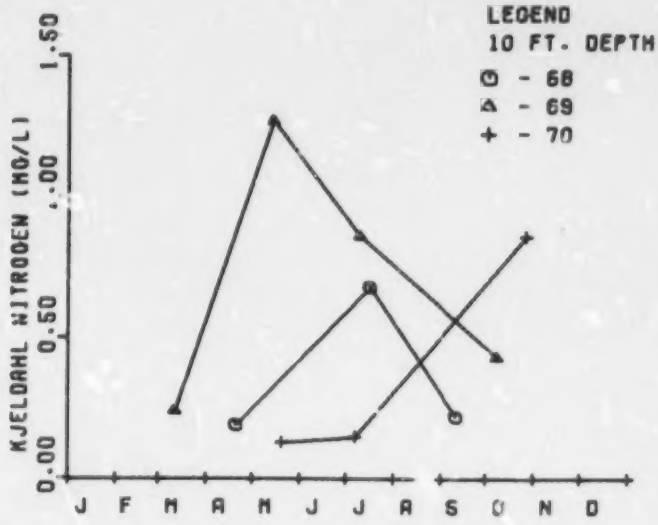
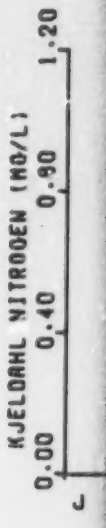
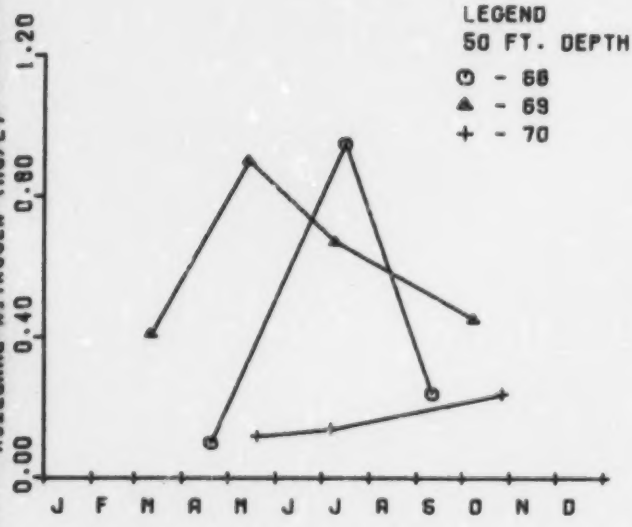


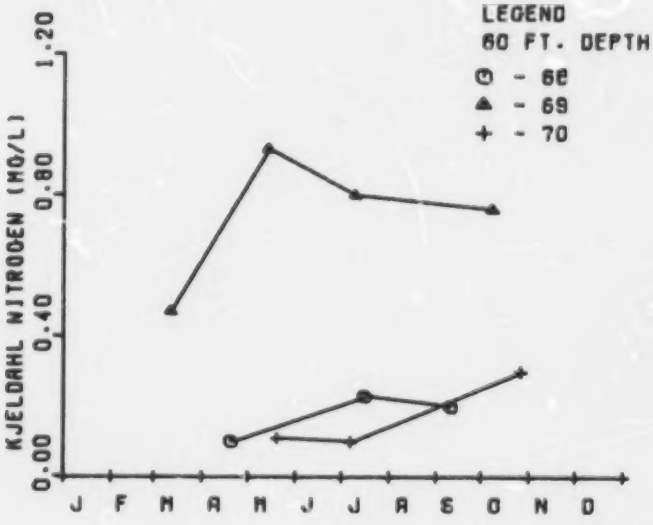
FIGURE 26. Dissolved Manganese Concentrations of Allatoona Lake at Station 1 for 1968, 1969 and 1970.

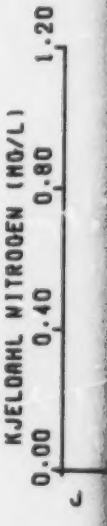

LEGEND
0 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
KJELDAHL NITROGEN (MG/L)
0.00
0.40
0.80
1.20
J F M A M J J A S O N D

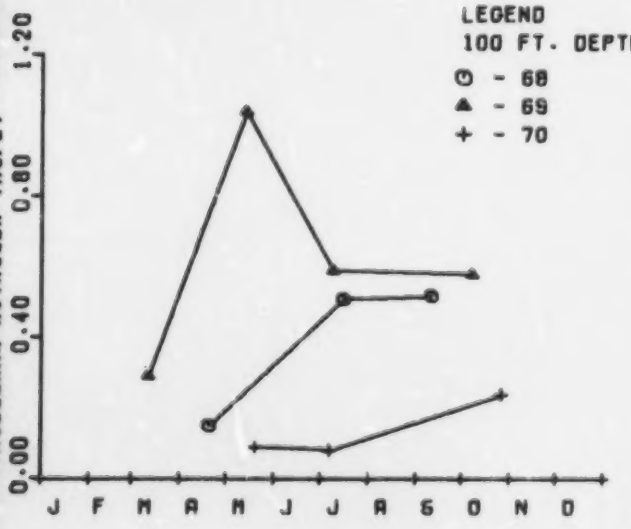

LEGEND
10 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
KJELDAHL NITROGEN (MG/L)
0.00
0.50
1.00
1.50
J F M A M J J A S O N D

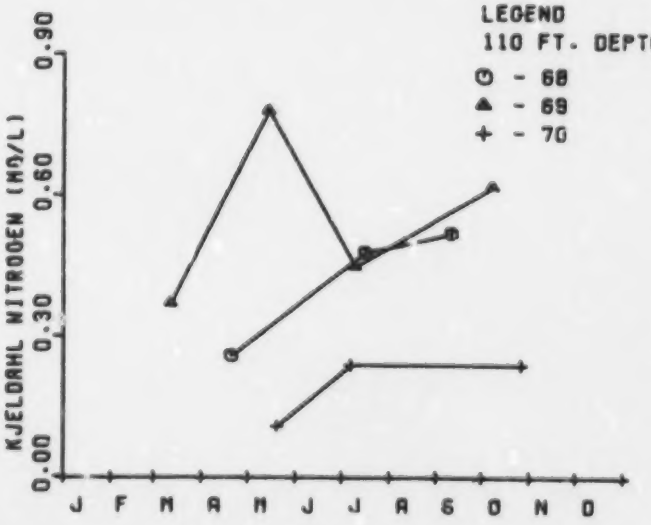

KJELDAHL NITROGEN (MG/L)
0.00
0.40
0.80
1.20

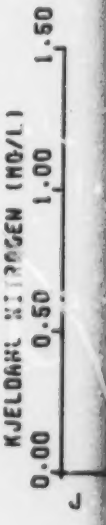

LEGEND
50 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
KJELDAHL NITROGEN (MG/L)
0.00
0.40
0.80
1.20
J F M A M J J A S O N D

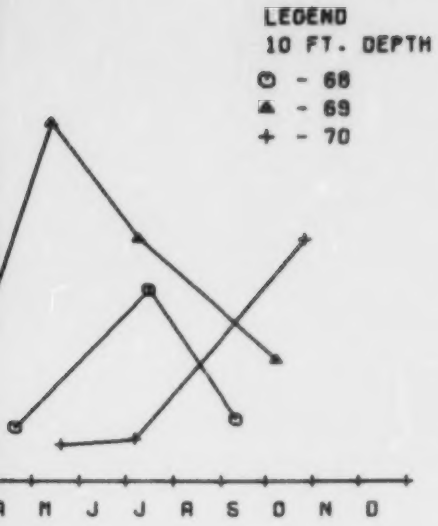

LEGEND
60 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
KJELDAHL NITROGEN (MG/L)
0.00
0.40
0.80
1.20
J F M A M J J A S O N D

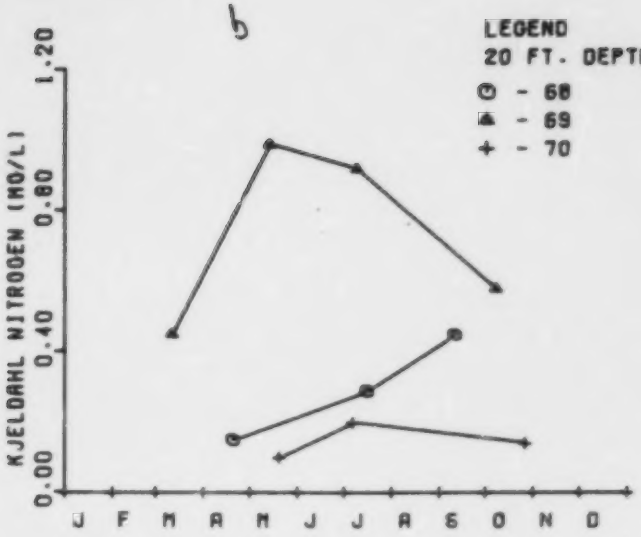

KJELDAHL NITROGEN (MG/L)
0.00
0.40
0.80
1.20

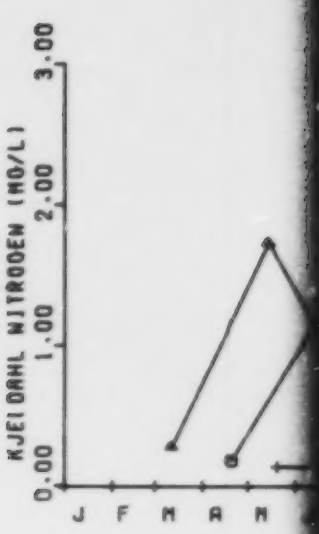

LEGEND
100 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
KJELDAHL NITROGEN (MG/L)
0.00
0.40
0.80
1.20
J F M A M J J A S O N D

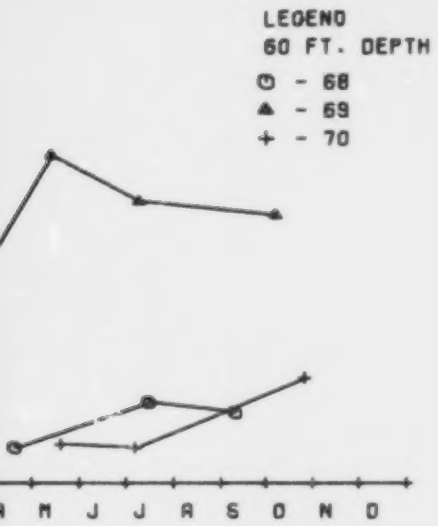

LEGEND
110 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
KJELDAHL NITROGEN (MG/L)
0.00
0.30
0.60
0.90
J F M A M J J A S O N D

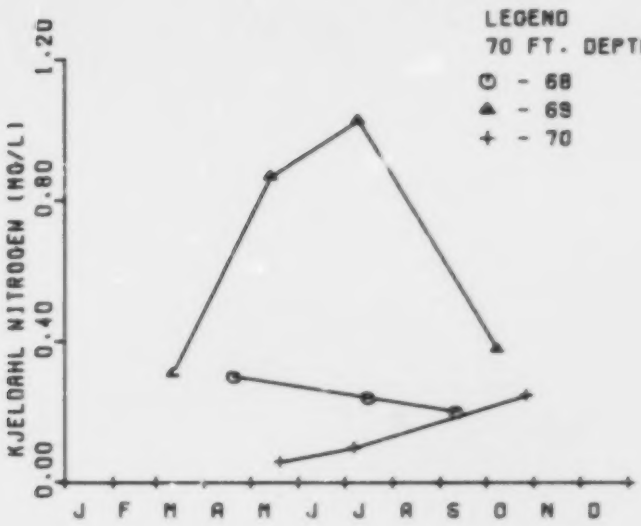

0.00
0.50
1.00
1.50

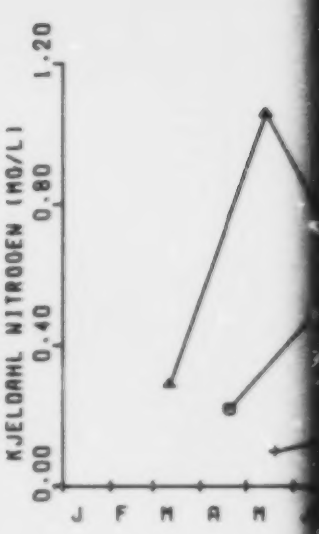

LEGEND
10 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
A M J J A S O N D

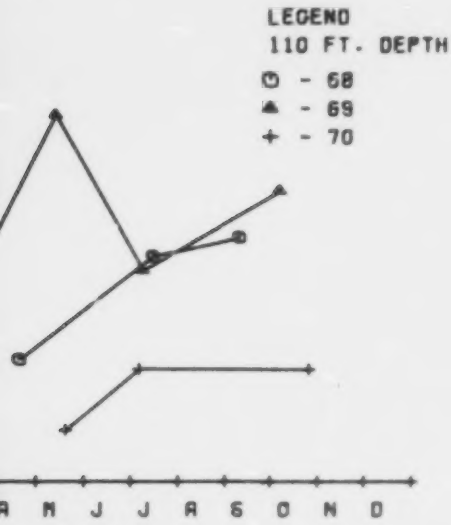

LEGEND
20 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
KJELDAHL NITROGEN (MG/L)
0.00
0.40
0.80
1.20
J F M A M J J A S O N D

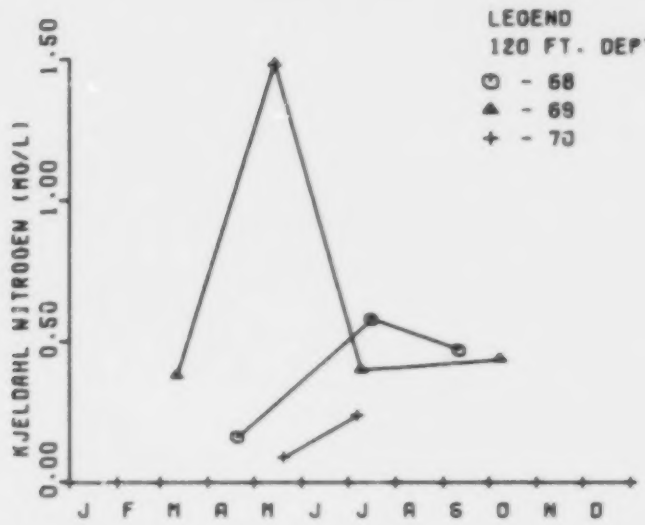

KJELDAHL NITROGEN (MG/L)
0.00
1.00
2.00
3.00
J F M A M

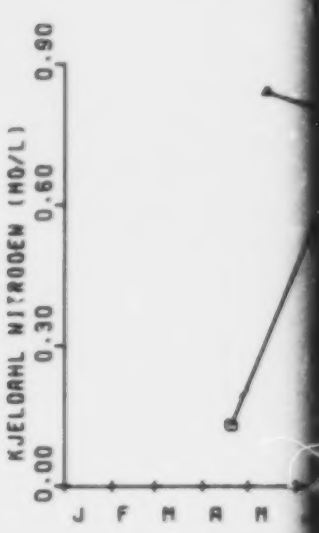

LEGEND
60 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
A M J J A S O N D


LEGEND
70 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
KJELDAHL NITROGEN (MG/L)
0.00
0.40
0.80
1.20
J F M A M J J A S O N D


KJELDAHL NITROGEN (MG/L)
0.00
0.40
0.80
1.20
J F M A M


LEGEND
110 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
A M J J A S O N D


LEGEND
120 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
KJELDAHL NITROGEN (MG/L)
0.00
0.50
1.00
1.50
J F M A M J J A S O N D


KJELDAHL NITROGEN (MG/L)
0.00
0.30
0.60
0.90
J F M A M

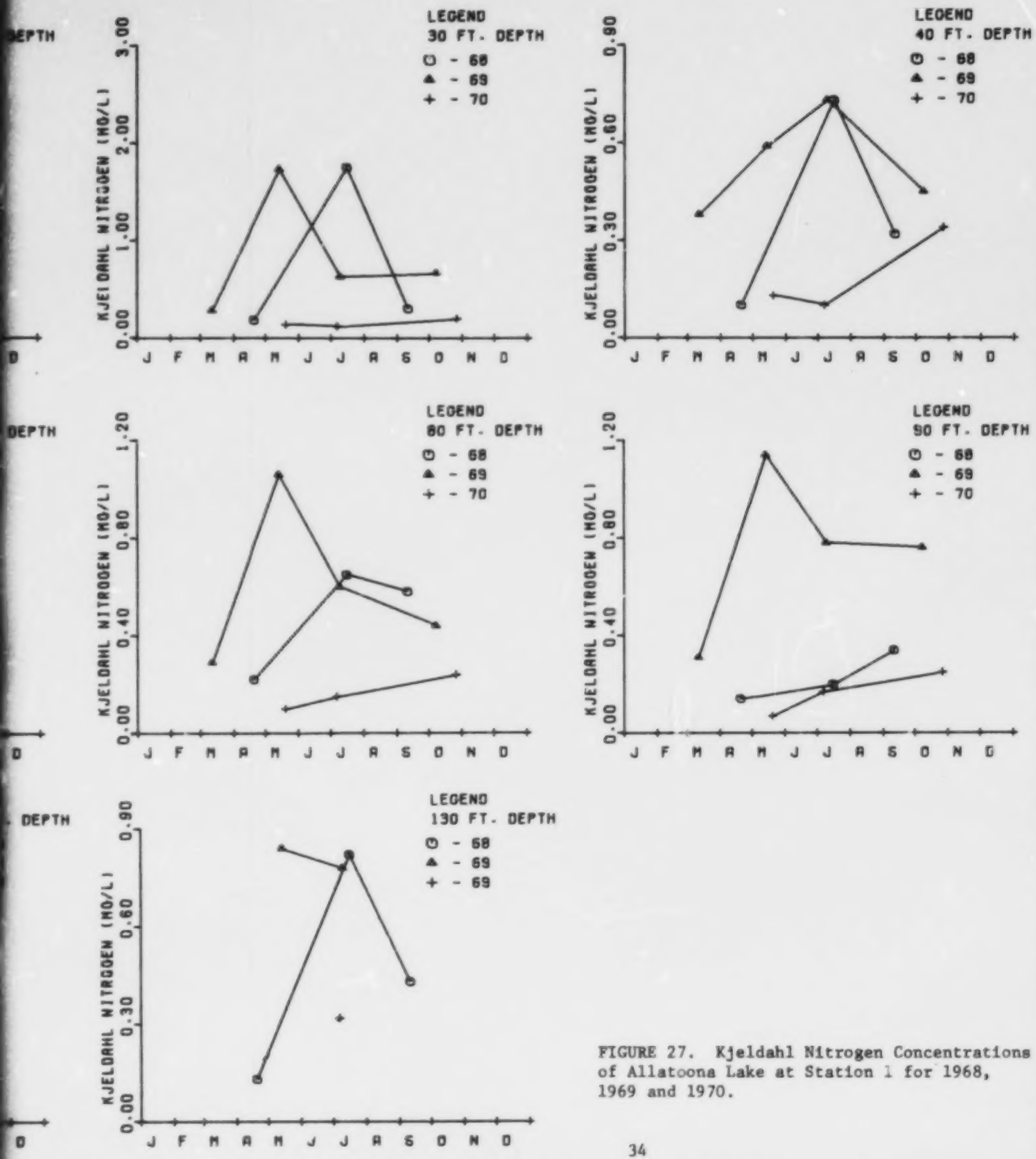
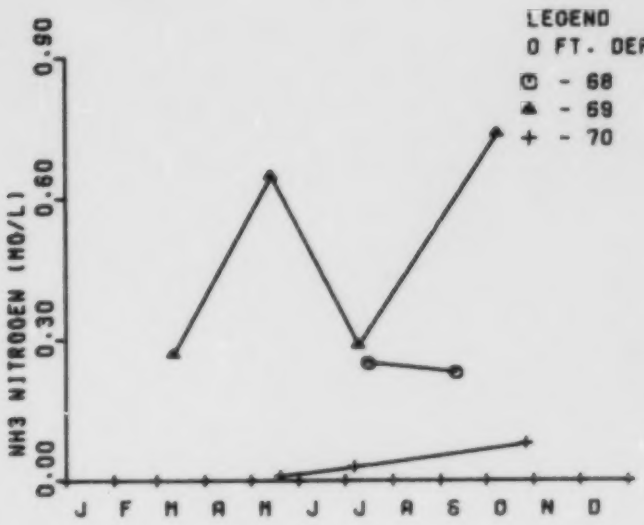
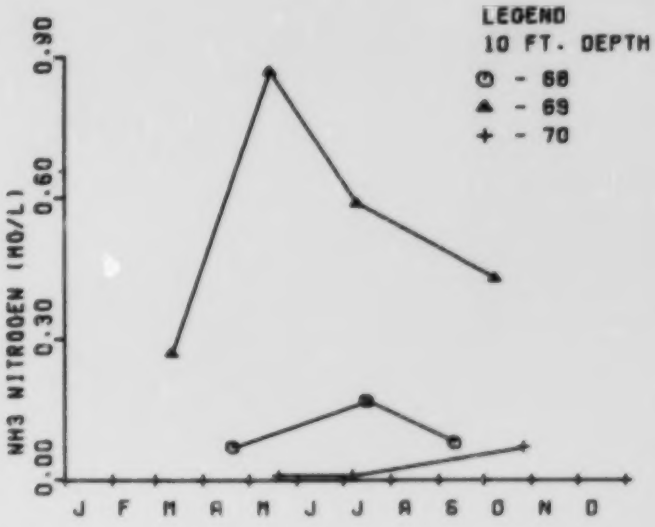
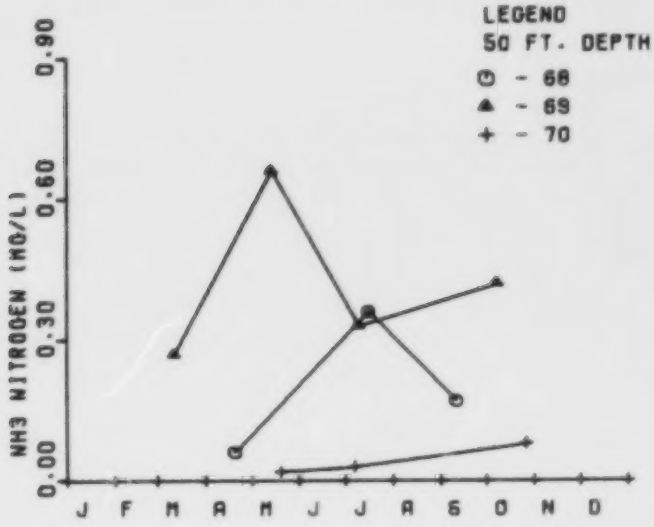
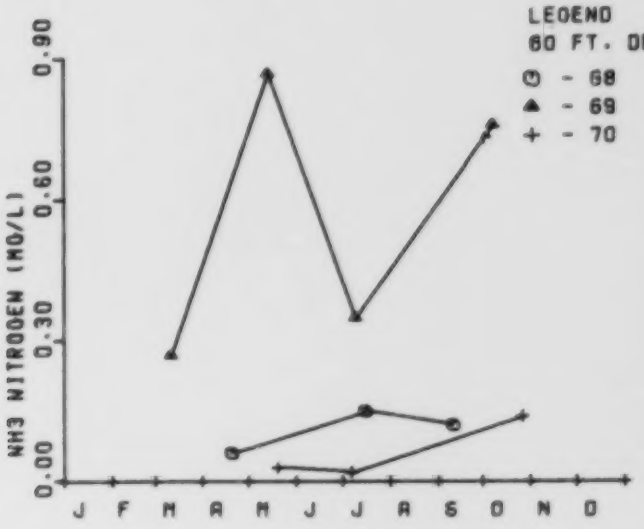


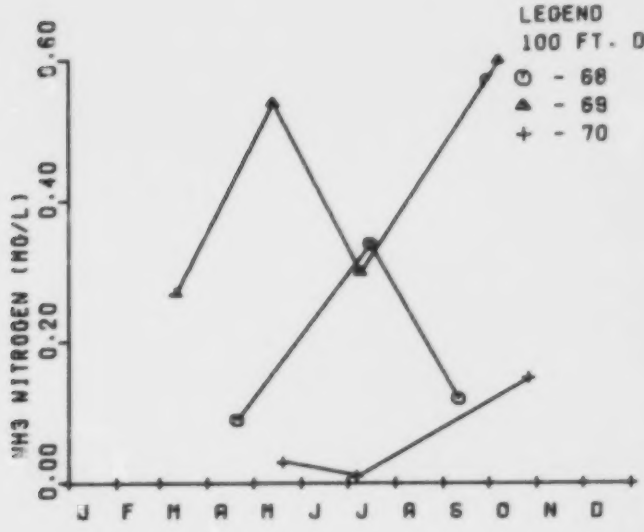
FIGURE 27. Kjeldahl Nitrogen Concentrations of Allatoona Lake at Station 1 for 1968, 1969 and 1970.

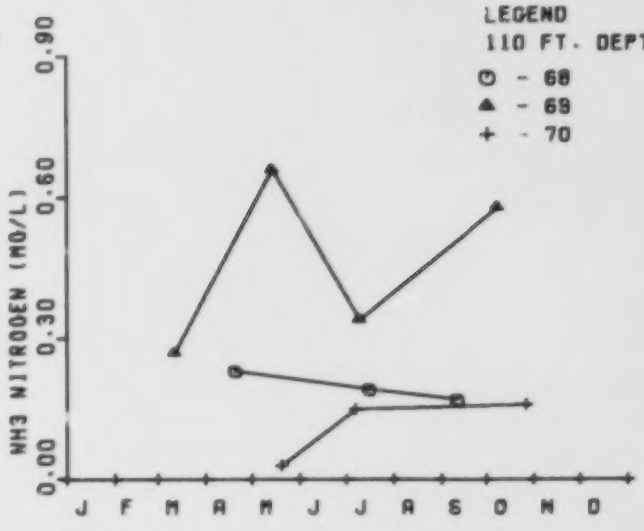

LEGEND
0 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
NH3 NITROGEN (MG/L)
0.00
0.30
0.60
0.90
J F M A M J J A S O N D

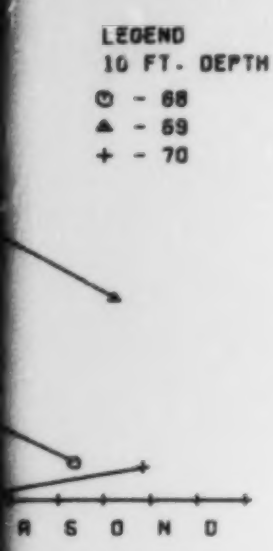

LEGEND
10 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
NH3 NITROGEN (MG/L)
0.00
0.30
0.60
0.90
J F M A M J J A S O N D

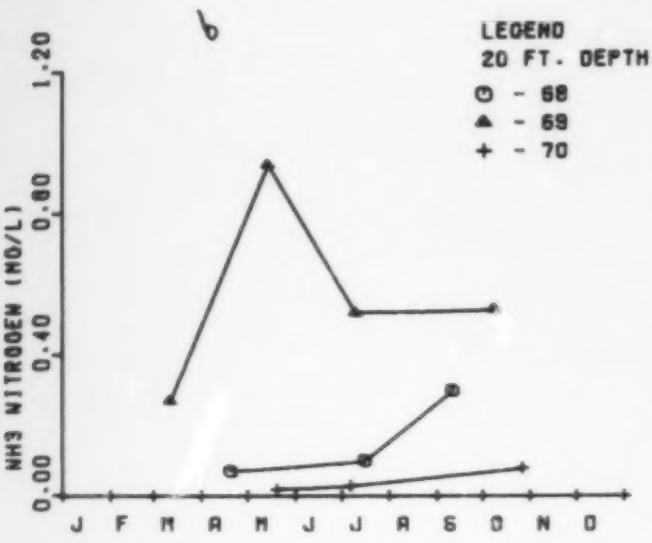

LEGEND
50 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
NH3 NITROGEN (MG/L)
0.00
0.30
0.60
0.90
J F M A M J J A S O N D

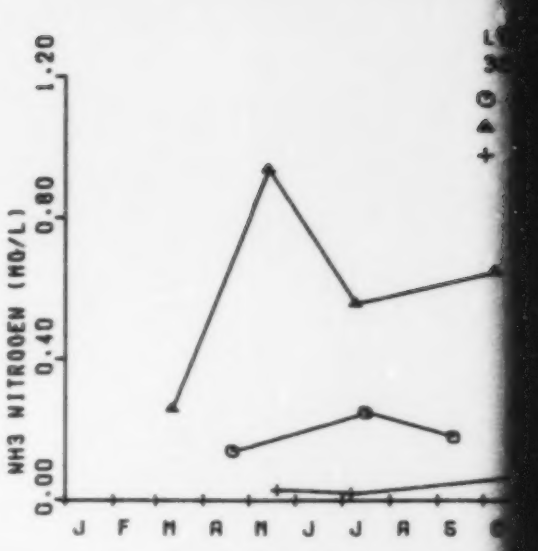

LEGEND
60 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
NH3 NITROGEN (MG/L)
0.00
0.30
0.60
0.90
J F M A M J J A S O N D

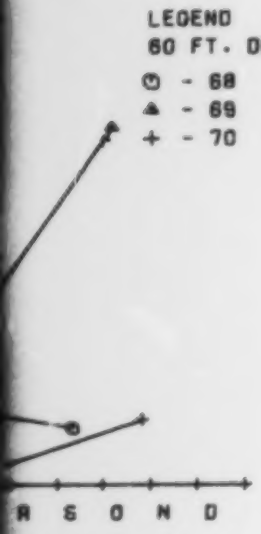

LEGEND
100 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
NH3 NITROGEN (MG/L)
0.00
0.20
0.40
0.60
J F M A M J J A S O N D

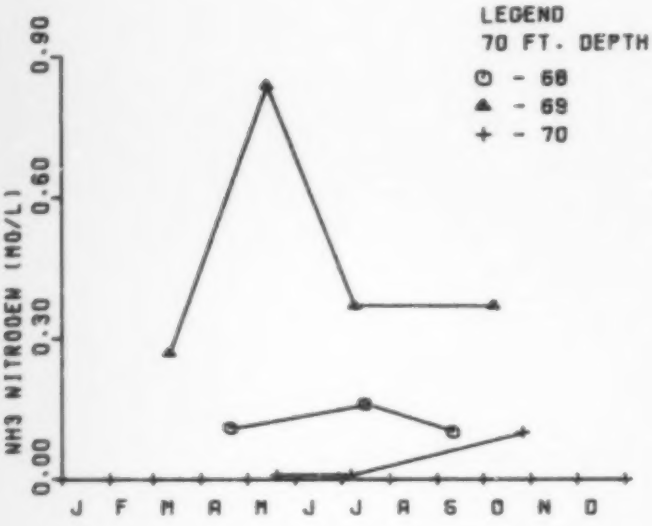

LEGEND
110 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
NH3 NITROGEN (MG/L)
0.00
0.30
0.60
0.90
J F M A M J J A S O N D

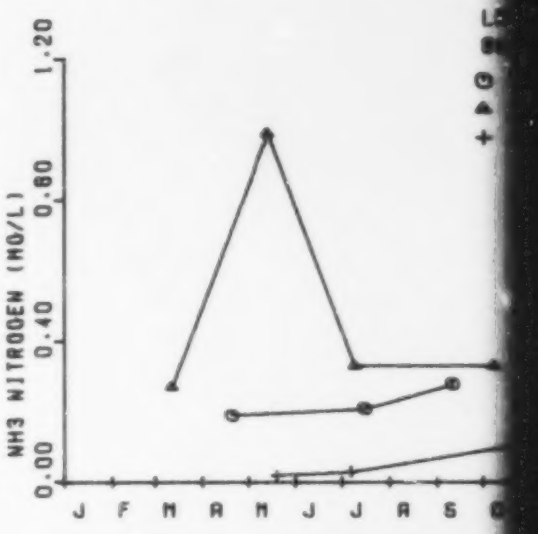

LEGEND
10 FT. DEPTH
- 68
- 69
- 70
A S O N D

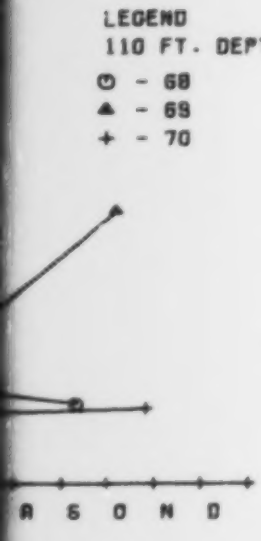

LEGEND
20 FT. DEPTH
- 68
- 69
- 70
NH3 NITROGEN (MG/L)
0.00
0.40
0.80
1.20
J F M A M J J A S O N D

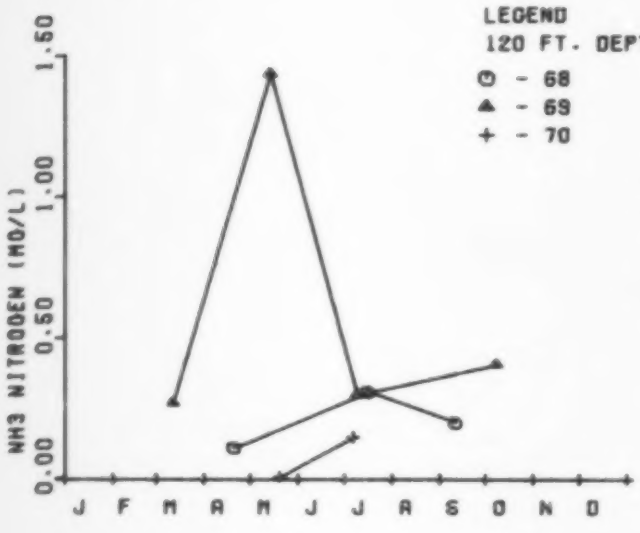

NH3 NITROGEN (MG/L)
0.00
0.40
0.80
1.20
J F M A M J J A S

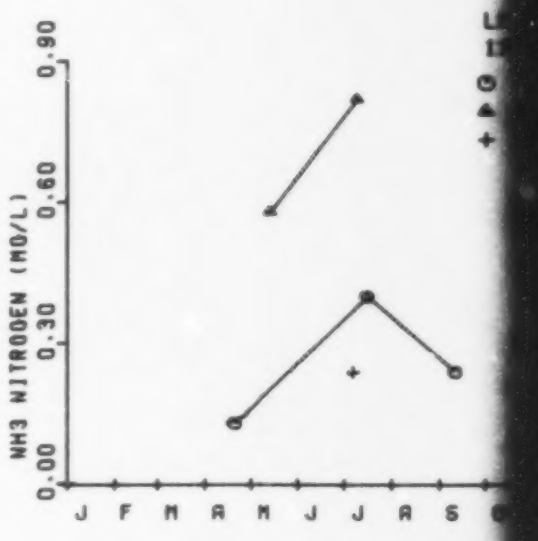

LEGEND
60 FT. DEPTH
- 68
- 69
- 70
A S O N D


LEGEND
70 FT. DEPTH
- 68
- 69
- 70
NH3 NITROGEN (MG/L)
0.00
0.30
0.60
0.90
J F M A M J J A S O N D


NH3 NITROGEN (MG/L)
0.00
0.40
0.80
1.20
J F M A M J J A S


LEGEND
110 FT. DEPTH
- 68
- 69
- 70
A S O N D


LEGEND
120 FT. DEPTH
- 68
- 69
- 70
NH3 NITROGEN (MG/L)
0.00
0.50
1.00
1.50
J F M A M J J A S O N D


NH3 NITROGEN (MG/L)
0.00
0.30
0.60
0.90
J F M A M J J A S

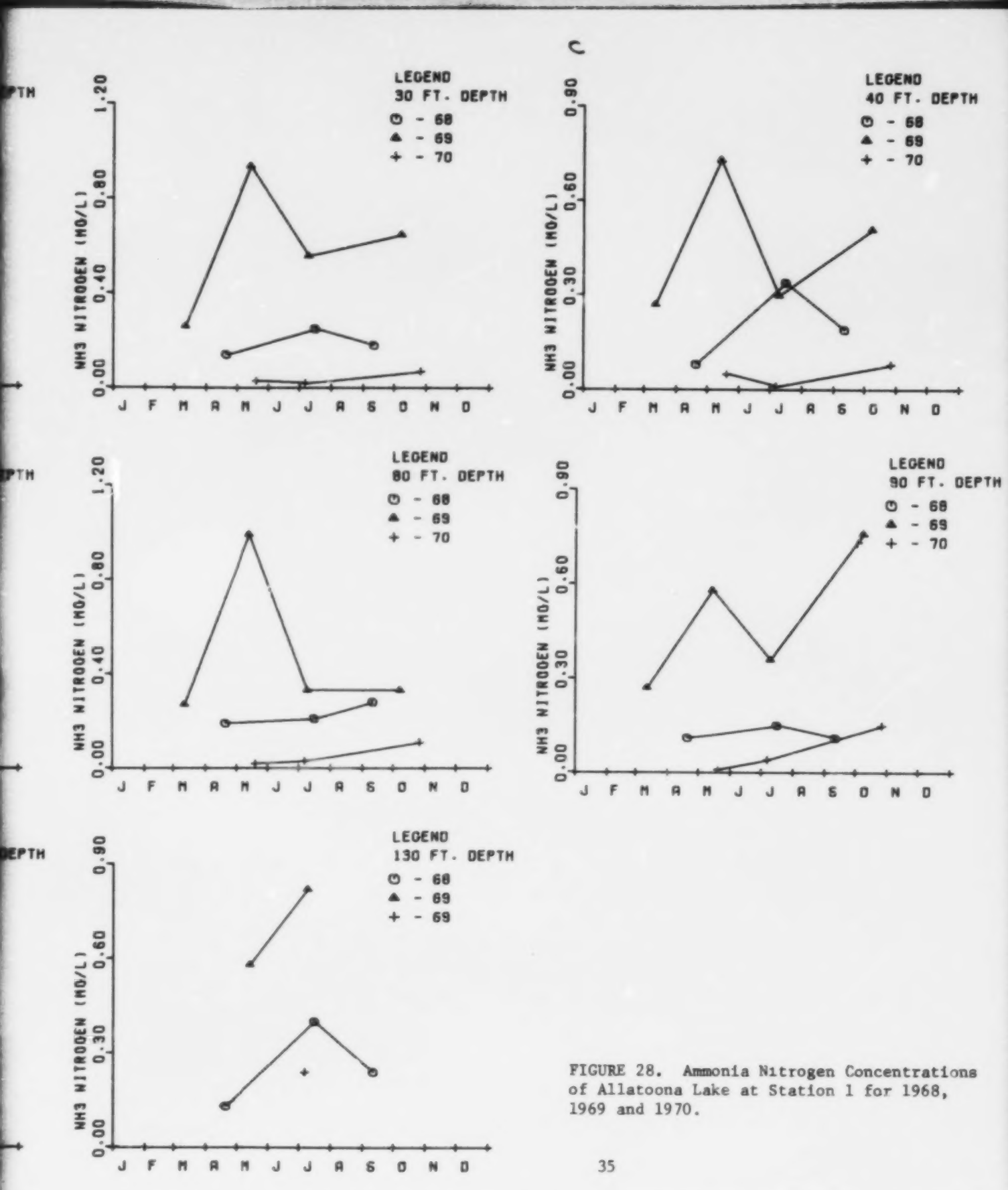
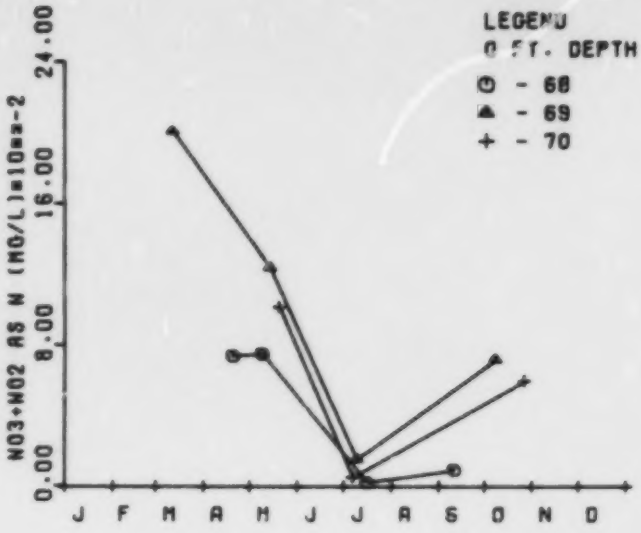
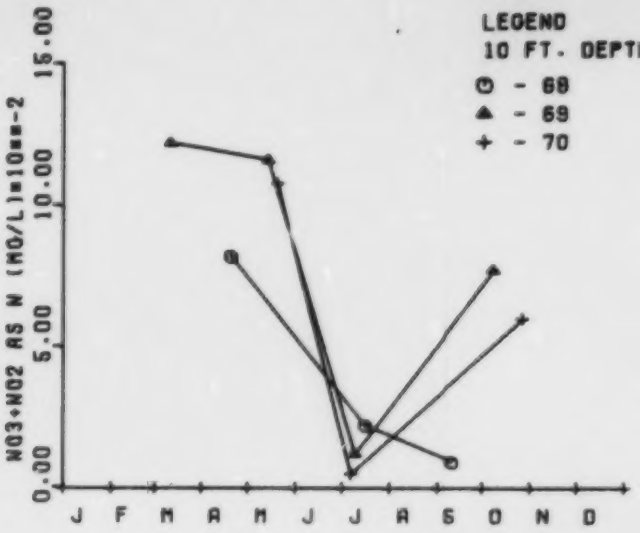
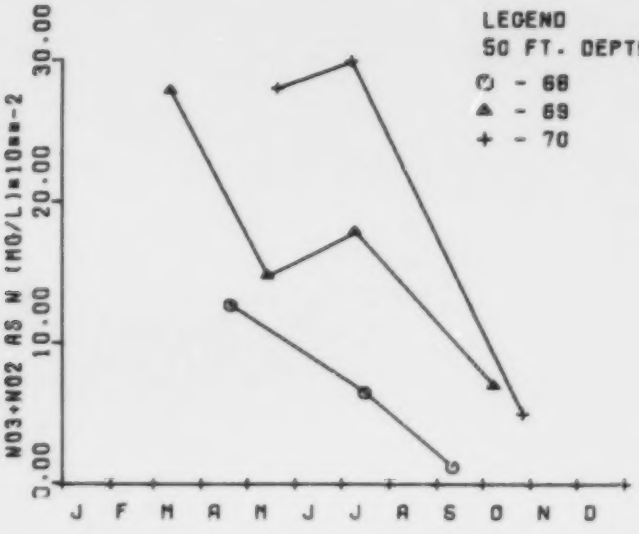
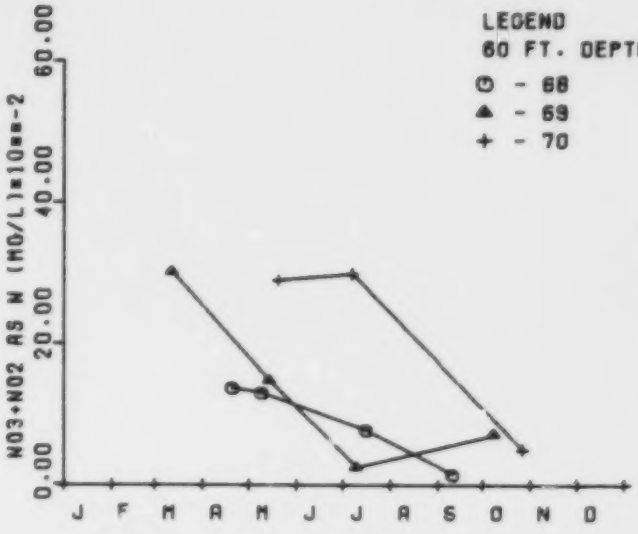


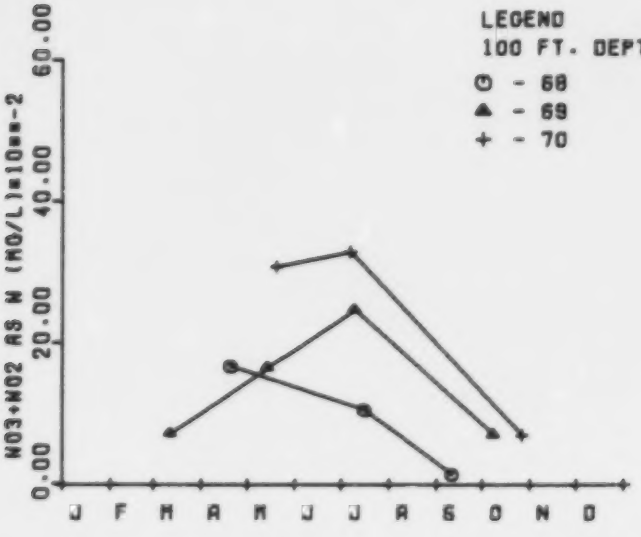
FIGURE 28. Ammonia Nitrogen Concentrations of Allatoona Lake at Station 1 for 1968, 1969 and 1970.

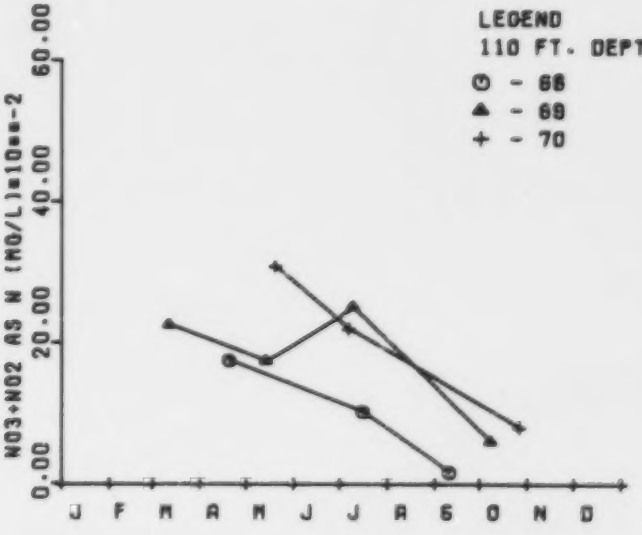

LEGEND
0 FT. DEPTH
68
69
70
NO3+NO2 AS N (MG/L)=10**-2
0.00
8.00
16.00
24.00
J F M A M J J A S O N D

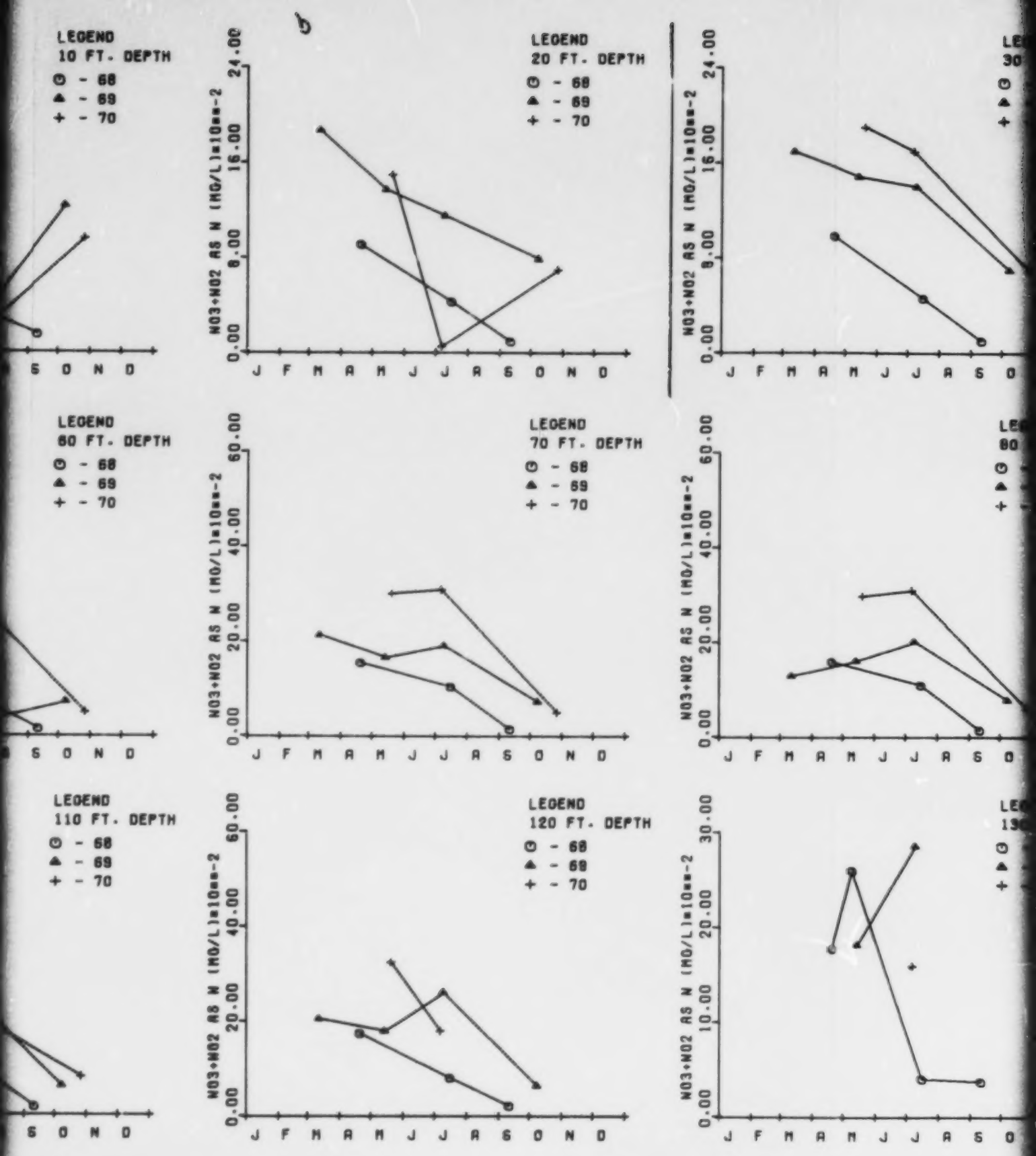

LEGEND
10 FT. DEPTH
68
69
70
NO3+NO2 AS N (MG/L)=10**-2
0.00
5.00
10.00
15.00
J F M A M J J A S O N D


LEGEND
50 FT. DEPTH
68
69
70
NO3+NO2 AS N (MG/L)=10**-2
0.00
10.00
20.00
30.00
J F M A M J J A S O N D


LEGEND
60 FT. DEPTH
68
69
70
NO3+NO2 AS N (MG/L)=10**-2
0.00
20.00
40.00
60.00
J F M A M J J A S O N D


LEGEND
100 FT. DEPTH
68
69
70
NO3+NO2 AS N (MG/L)=10**-2
0.00
20.00
40.00
60.00
J F M A M J J A S O N D


LEGEND
110 FT. DEPTH
68
69
70
NO3+NO2 AS N (MG/L)=10**-2
0.00
20.00
40.00
60.00
J F M A M J J A S O N D


LEGEND
10 FT. DEPTH
68
69
70
LEGEND
20 FT. DEPTH
68
69
70
NO3+NO2 AS N (MG/L)=10**-2
24.00
16.00
8.00
0.00
J F M A M J J A S O N D
LEGEND
60 FT. DEPTH
68
69
70
LEGEND
70 FT. DEPTH
68
69
70
60.00
40.00
20.00
0.00
LEGEND
110 FT. DEPTH
68
69
70
LEGEND
120 FT. DEPTH
68
69
70
30.00
10.00

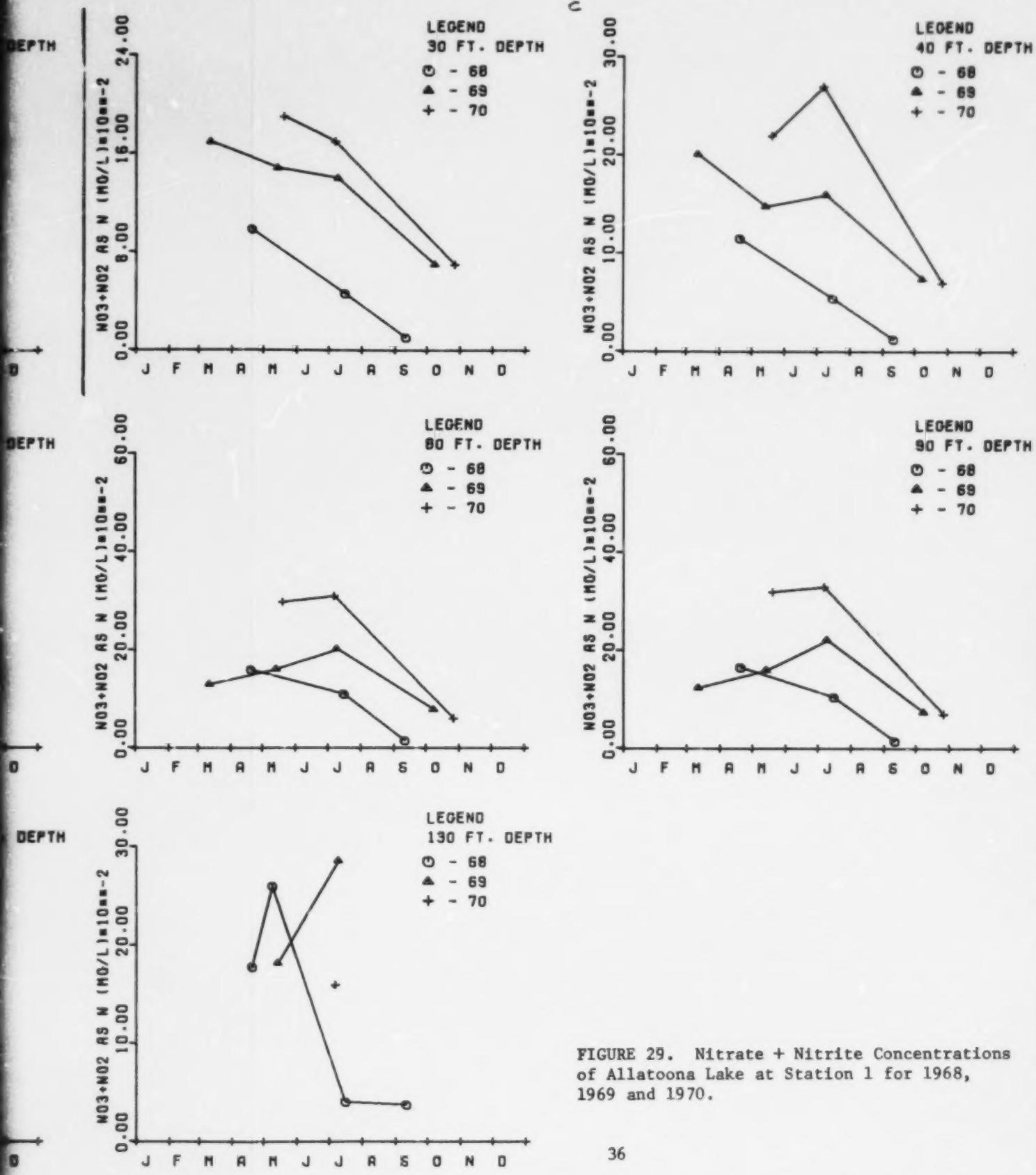
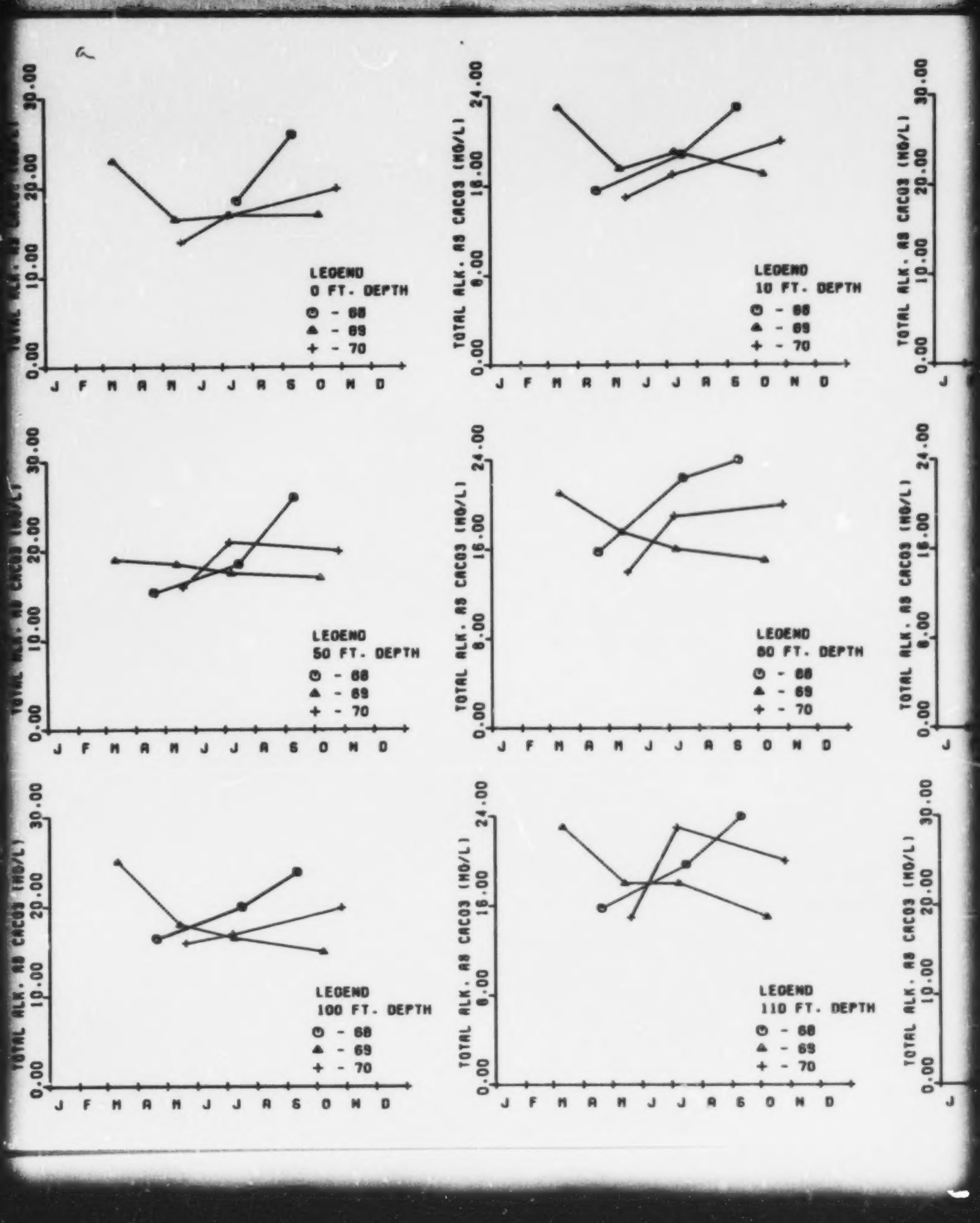
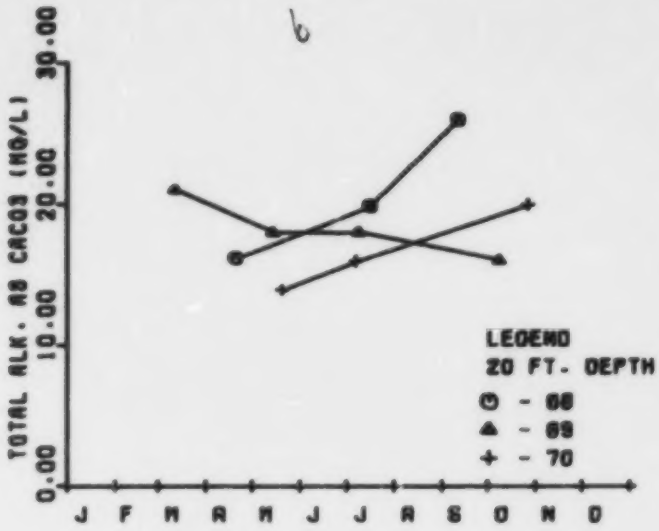
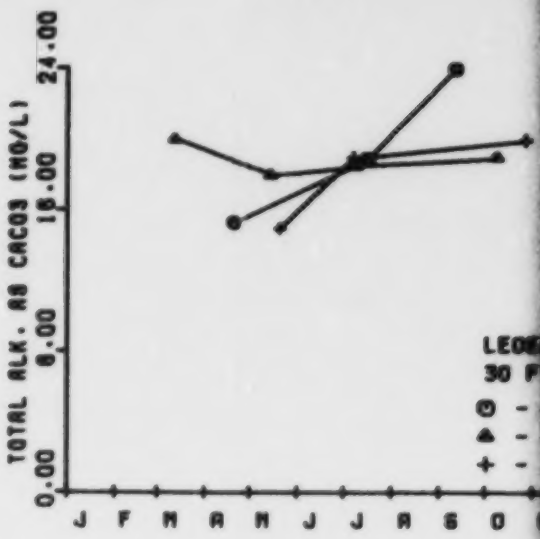


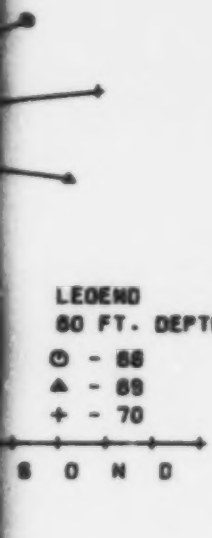
FIGURE 29. Nitrate + Nitrite Concentrations of Allatoona Lake at Station 1 for 1968, 1969 and 1970.

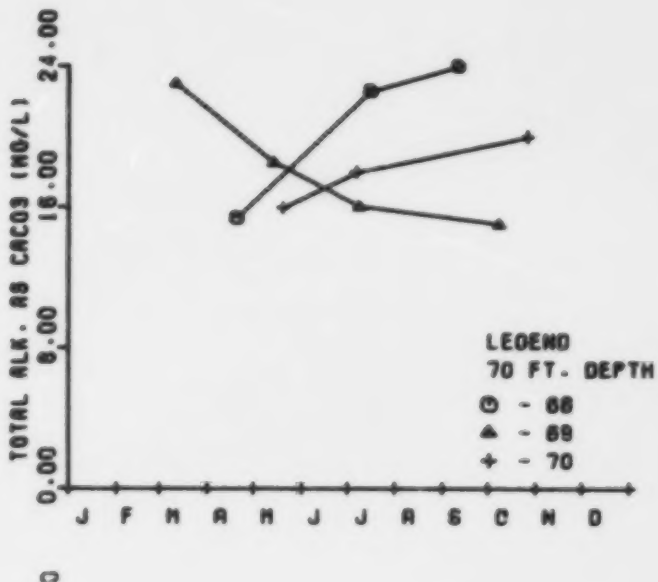

TOTAL ALK. AS CACO3 (MG/L)
0.00
10.00
20.00
30.00
J F M A M J J A S O N D
LEGEND
0 FT. DEPTH
68
69
70
TOTAL ALK. AS CACO3 (MG/L)
0.00
8.00
16.00
24.00
J F M A M J J A S O N D
LEGEND
10 FT. DEPTH
68
69
70
TOTAL ALK. AS CACO3 (MG/L)
0.00
10.00
20.00
30.00
J
TOTAL ALK. AS CACO3 (MG/L)
0.00
10.00
20.00
30.00
J F M A M J J A S O N D
LEGEND
50 FT. DEPTH
68
69
70
TOTAL ALK. AS CACO3 (MG/L)
0.00
8.00
16.00
24.00
J F M A M J J A S O N D
LEGEND
80 FT. DEPTH
68
69
70
TOTAL ALK. AS CACO3 (MG/L)
0.00
8.00
16.00
24.00
J
TOTAL ALK. AS CACO3 (MG/L)
0.00
10.00
20.00
30.00
J F M A M J J A S O N D
LEGEND
100 FT. DEPTH
68
69
70
TOTAL ALK. AS CACO3 (MG/L)
0.00
8.00
16.00
24.00
J F M A M J J A S O N D
LEGEND
110 FT. DEPTH
68
69
70
TOTAL ALK. AS CACO3 (MG/L)
0.00
10.00
20.00
30.00
J

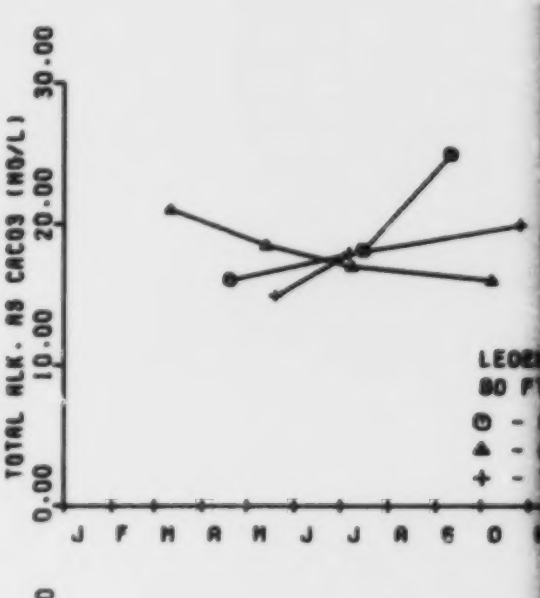
LEGEND
10 FT. DEPTH
68
69
70
S O N D

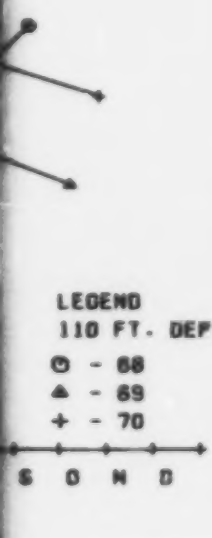

TOTAL ALK. AS CACO3 (MG/L)
30.00
20.00
10.00
0.00
LEGEND
20 FT. DEPTH
68
69
70
J F M A M J J A S O N D

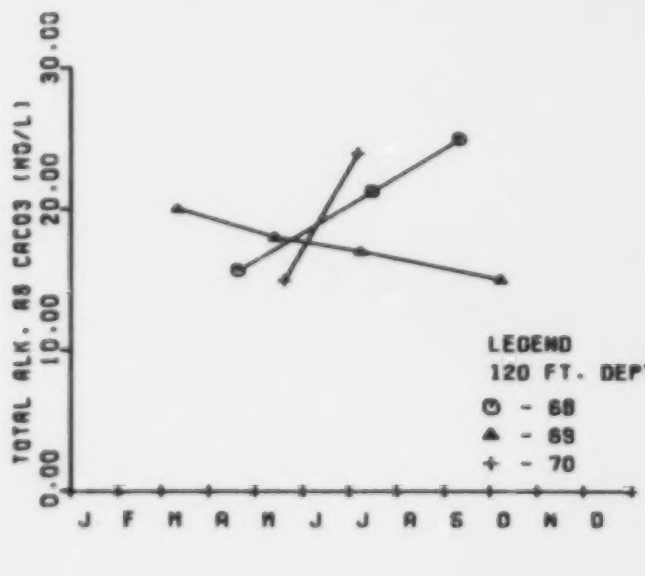

TOTAL ALK. AS CACO3 (MG/L)
24.00
16.00
8.00
0.00
LEGE
30 F
J F M A M J J A S O

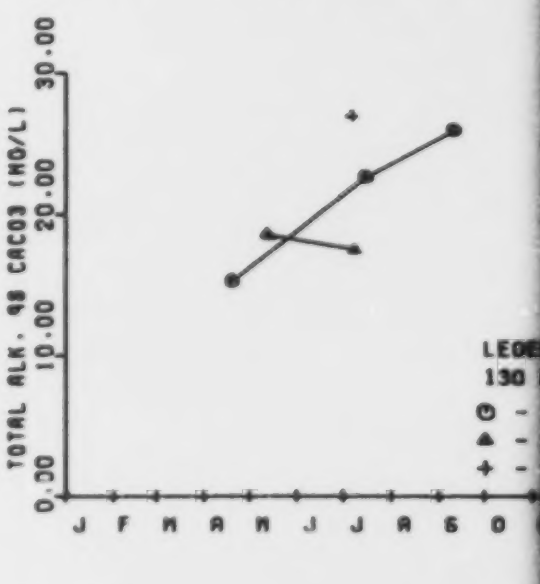

LEGEND
60 FT. DEPTH
68
69
70
S O N D


TOTAL ALK. AS CACO3 (MG/L)
24.00
16.00
8.00
0.00
LEGEND
70 FT. DEPTH
68
69
70
J F M A M J J A S O N D


TOTAL ALK. AS CACO3 (MG/L)
30.00
20.00
10.00
0.00
LEGE
80 F
J F M A M J J A S O


LEGEND
110 FT. DEPTH
68
69
70
S O N D


TOTAL ALK. AS CACO3 (MG/L)
30.00
20.00
10.00
0.00
LEGEND
120 FT. DEPTH
68
69
70
J F M A M J J A S O N D


TOTAL ALK. AS CACO3 (MG/L)
30.00
20.00
10.00
0.00
LEGE
130
J F M A M J J A S O

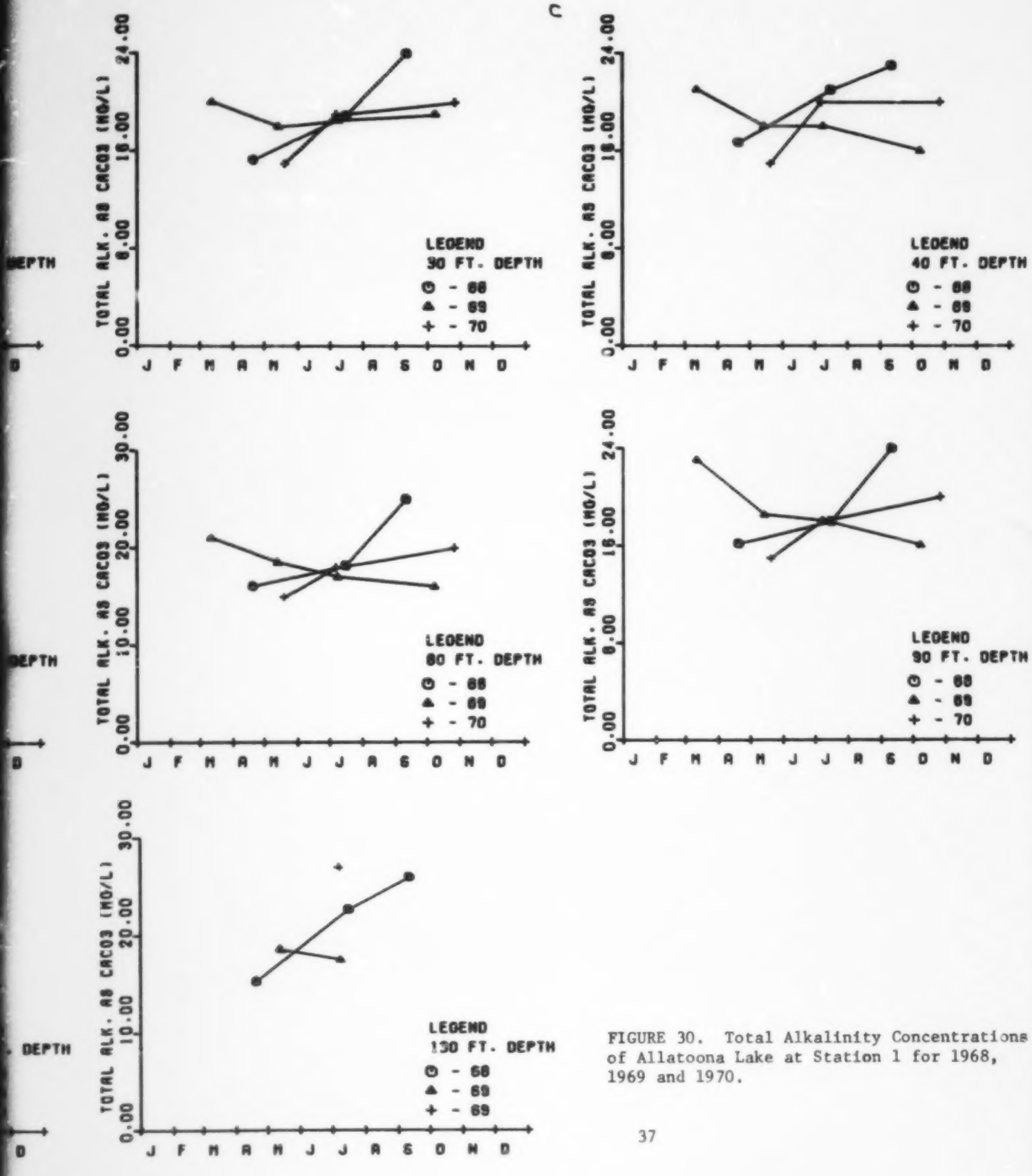
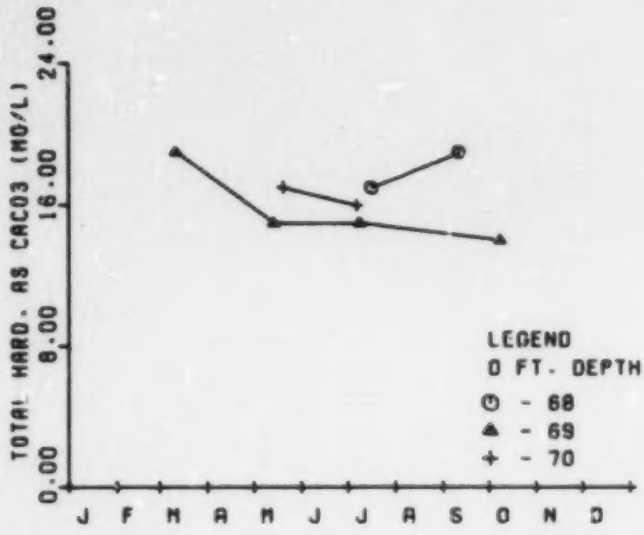
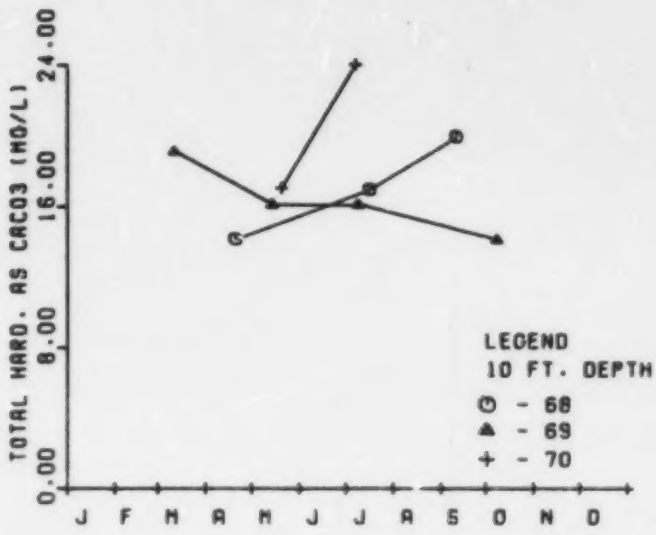
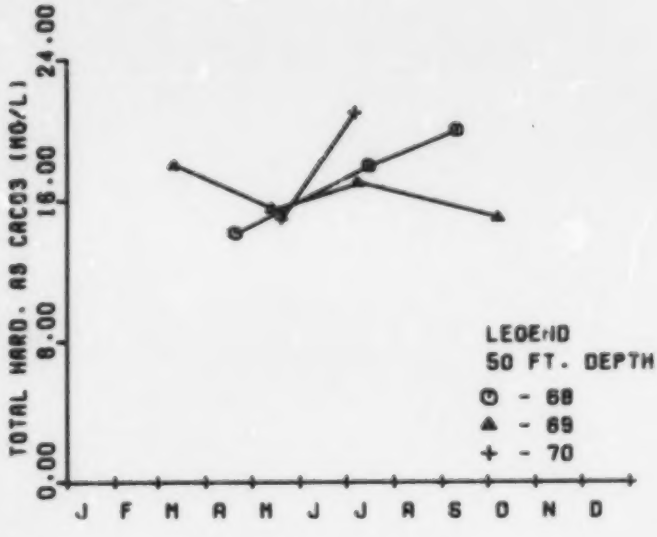
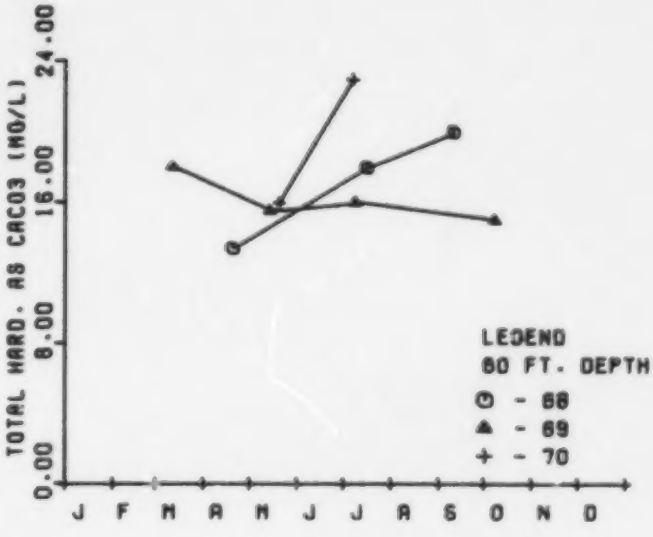


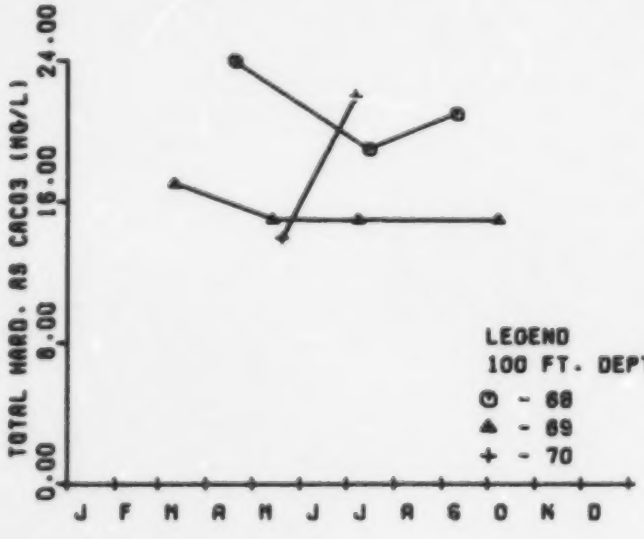
FIGURE 30. Total Alkalinity Concentrations of Allatoona Lake at Station 1 for 1968, 1969 and 1970.

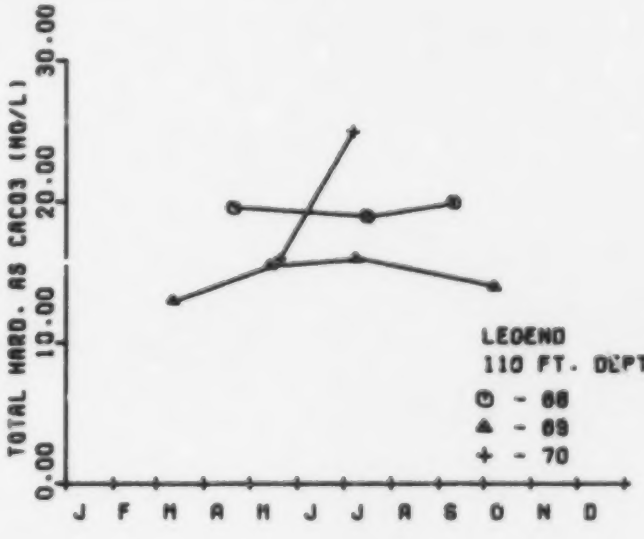

TOTAL HARD. AS CACO3 (MG/L)
0.00
8.00
16.00
24.00
J F M A M J J A S O N D
LEGEND
0 FT. DEPTH
G - 68
▲ - 69
+ - 70

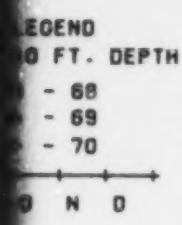

TOTAL HARD. AS CACO3 (MG/L)
0.00
8.00
16.00
24.00
J F M A M J J A S O N D
LEGEND
10 FT. DEPTH
G - 68
▲ - 69
+ - 70

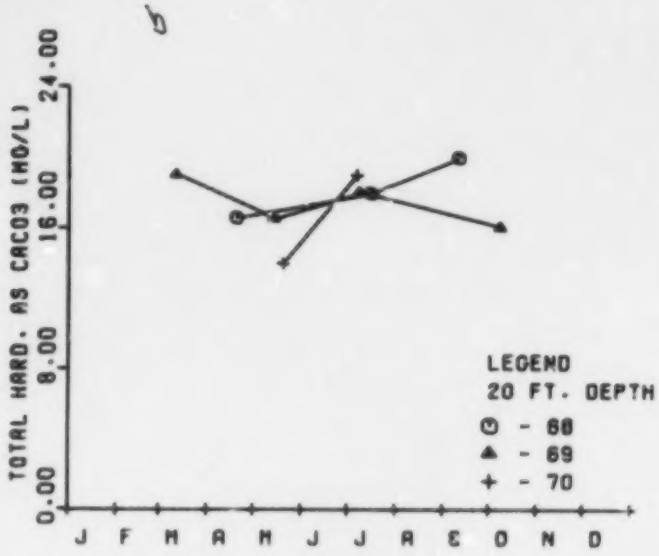

TOTAL HARD. AS CACO3 (MG/L)
0.00
8.00
16.00
24.00
J F M A M J J A S O N D
LEGEND
50 FT. DEPTH
G - 68
▲ - 69
+ - 70

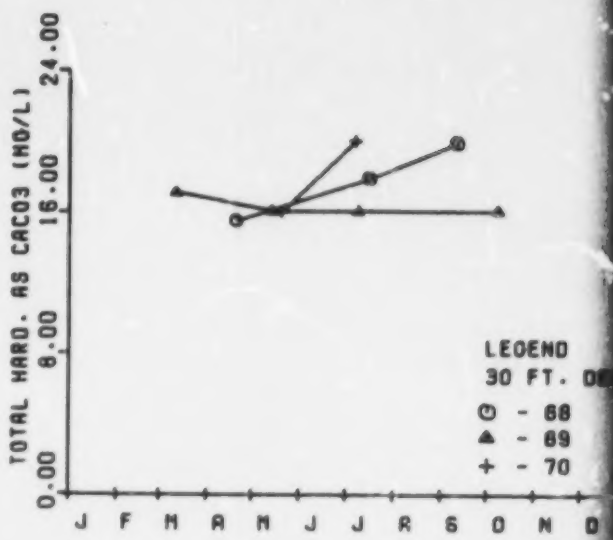

TOTAL HARD. AS CACO3 (MG/L)
0.00
8.00
16.00
24.00
J F M A M J J A S O N D
LEGEND
80 FT. DEPTH
G - 68
▲ - 69
+ - 70

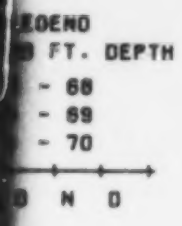

TOTAL HARD. AS CACO3 (MG/L)
0.00
8.00
16.00
24.00
J F M A M J J A S O N D
LEGEND
100 FT. DEPTH
G - 68
▲ - 69
+ - 70

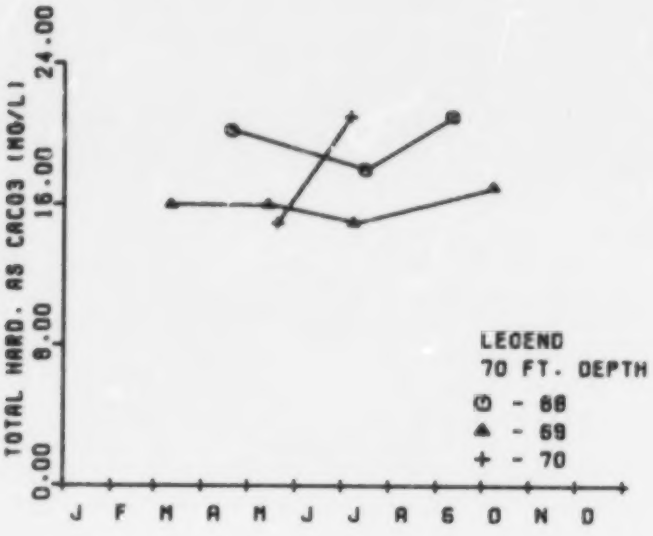

TOTAL HARD. AS CACO3 (MG/L)
0.00
10.00
20.00
30.00
J F M A M J J A S O N D
LEGEND
110 FT. DEPTH
G - 68
▲ - 69
+ - 70

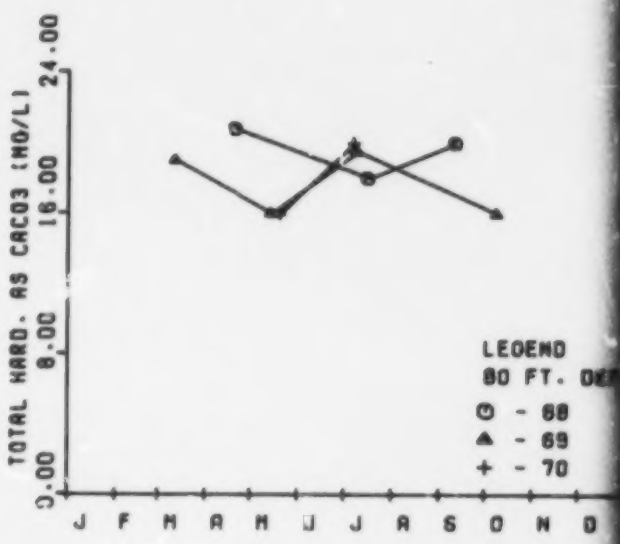

EGEND
0 FT. DEPTH
- 68
- 69
- 70
O N D

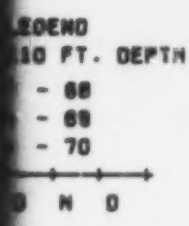

TOTAL HARD. AS CACO3 (MG/L)
24.00
16.00
8.00
0.00
J F M A M J J A S O N D
LEGEND
20 FT. DEPTH
- 68
- 69
- 70

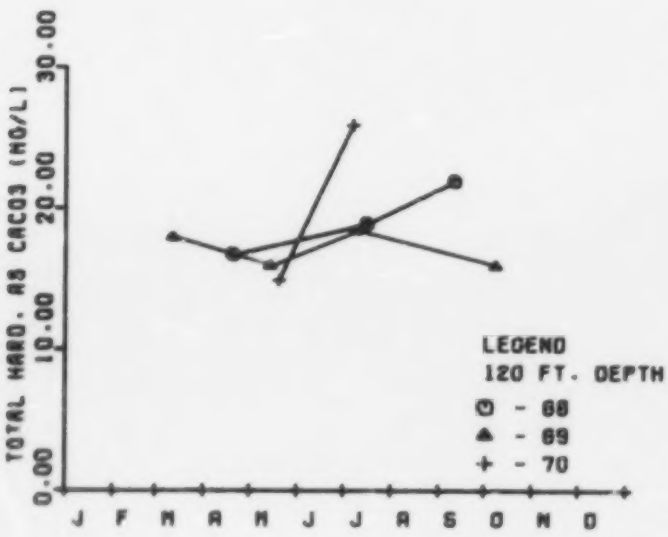

TOTAL HARD. AS CACO3 (MG/L)
24.00
16.00
8.00
0.00
J F M A M J J A S O N D
LEGEND
30 FT. DE
- 68
- 69
- 70

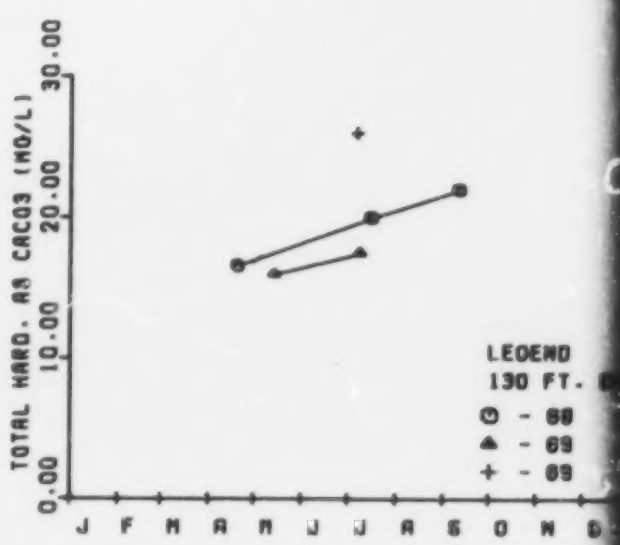

EGEND
FT. DEPTH
- 68
- 69
- 70
O N D

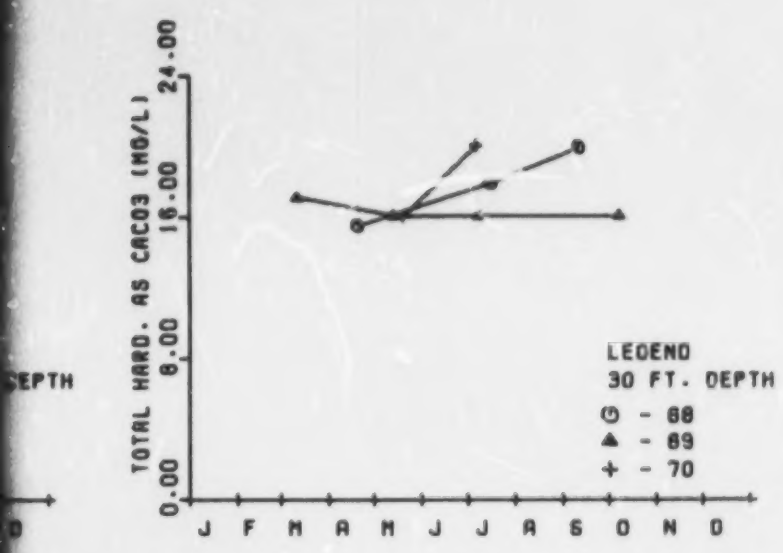

TOTAL HARD. AS CACO3 (MG/L)
24.00
16.00
8.00
0.00
J F M A M J J A S O N D
LEGEND
70 FT. DEPTH
- 68
- 69
- 70

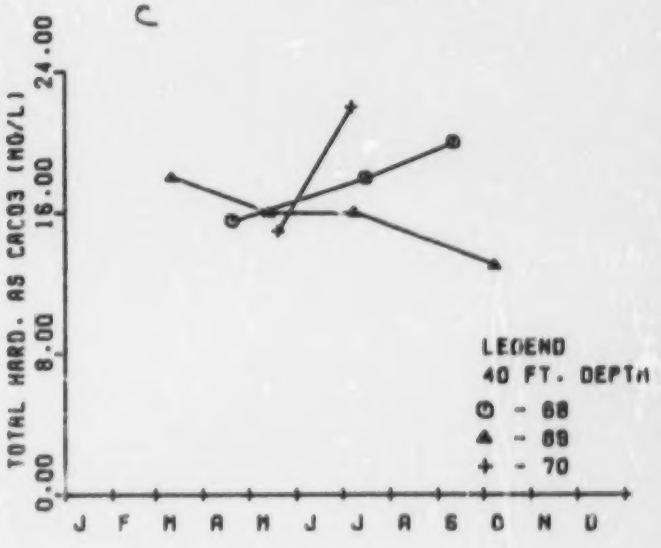

TOTAL HARD. AS CACO3 (MG/L)
24.00
16.00
8.00
0.00
J F M A M J J A S O N D
LEGEND
80 FT. DE
- 68
- 69
- 70

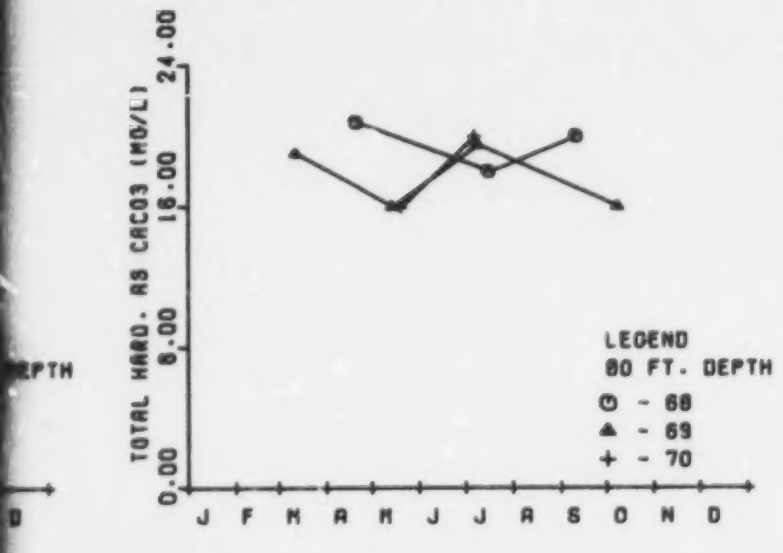

EGEND
0 FT. DEPTH
- 68
- 69
- 70
O N D

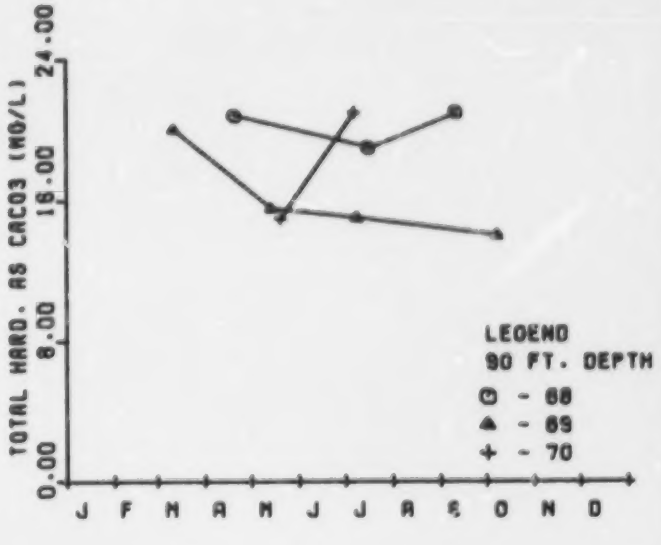

TOTAL HARD. AS CACO3 (MG/L)
30.00
20.00
10.00
0.00
J F M A M J J A S O N D
LEGEND
120 FT. DEPTH
- 68
- 69
- 70


TOTAL HARD. AS CACO3 (MG/L)
30.00
20.00
10.00
0.00
J F M A M J J A S O N D
LEGEND
130 FT.
- 68
- 69
- 70









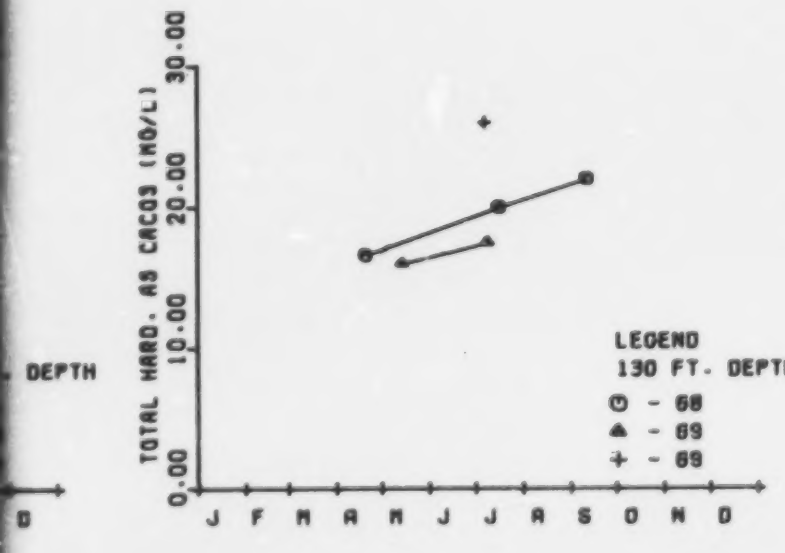
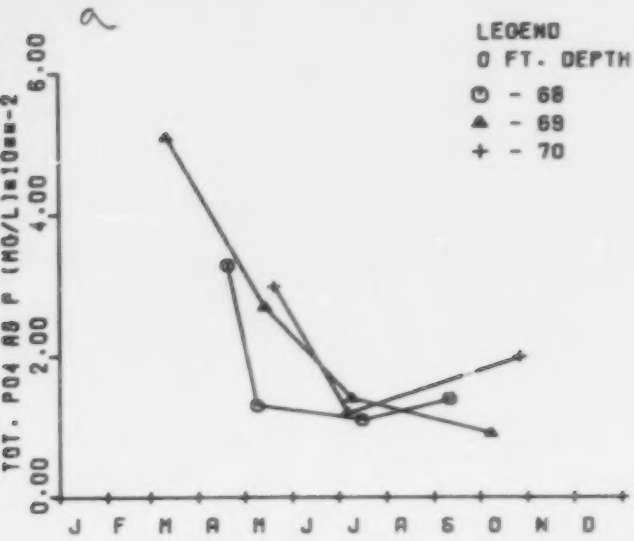
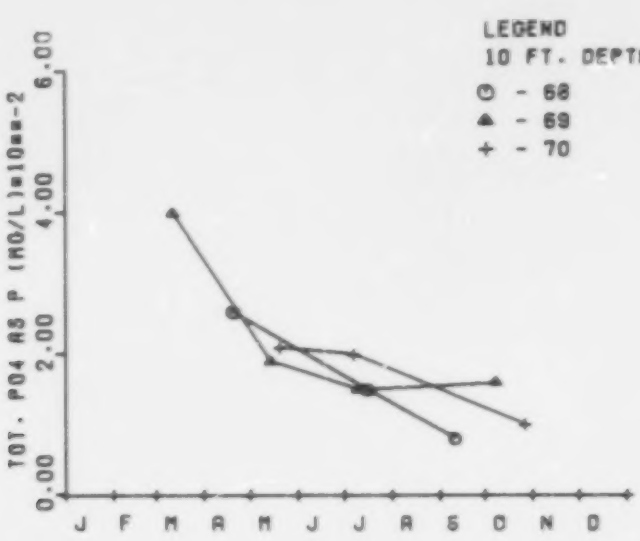
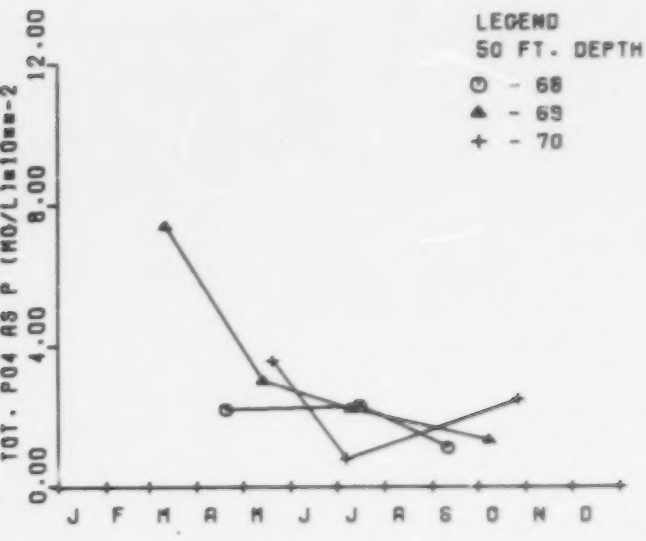


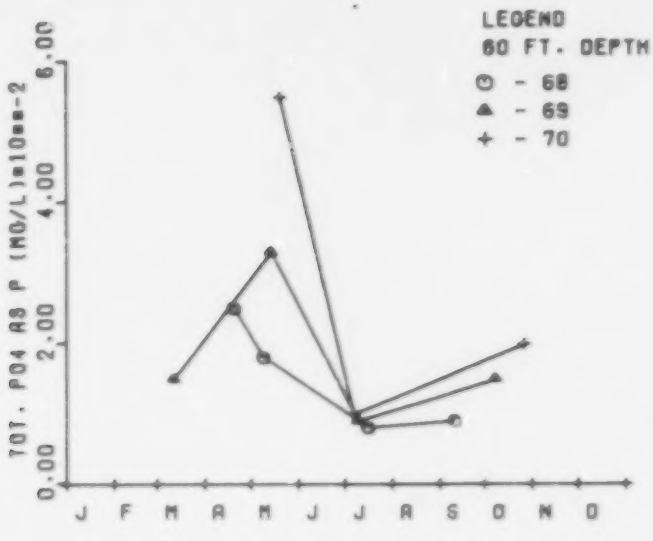
FIGURE 31. Total Hardness Concentrations of Allatoona Lake at Station 1 for 1968, 1969 and 1970.


LEGEND
0 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
TOT. PO4 AS P (MG/L)x10**-2
0.00
2.00
4.00
6.00
J F M A M J J A S O N D

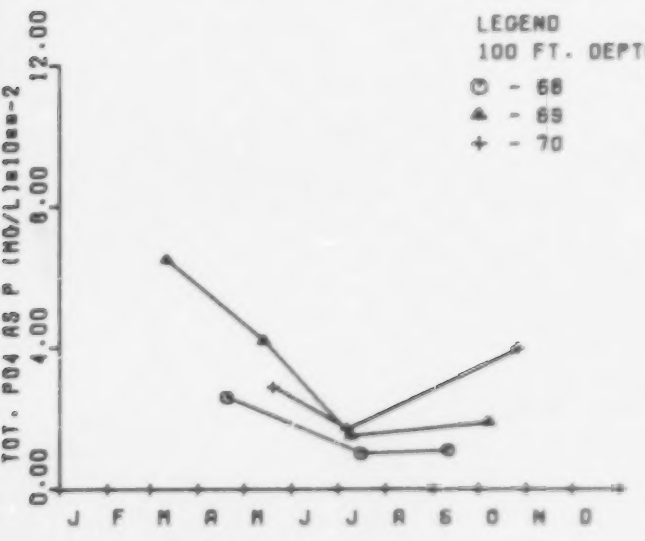

LEGEND
10 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
TOT. PO4 AS P (MG/L)x10**-2
0.00
2.00
4.00
6.00
J F M A M J J A S O N D

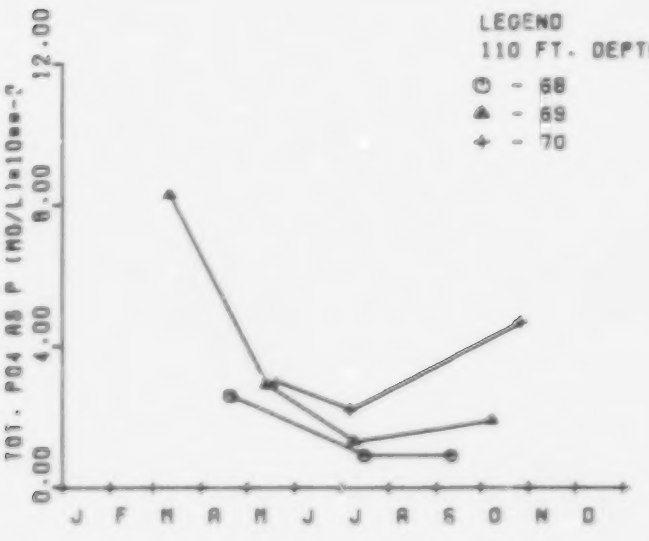
TOT. PO4 AS P (MG/L)x10**-2
0.00
1.00
2.00
3.00


LEGEND
50 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
TOT. PO4 AS P (MG/L)x10**-2
0.00
4.00
8.00
12.00
J F M A M J J A S O N D

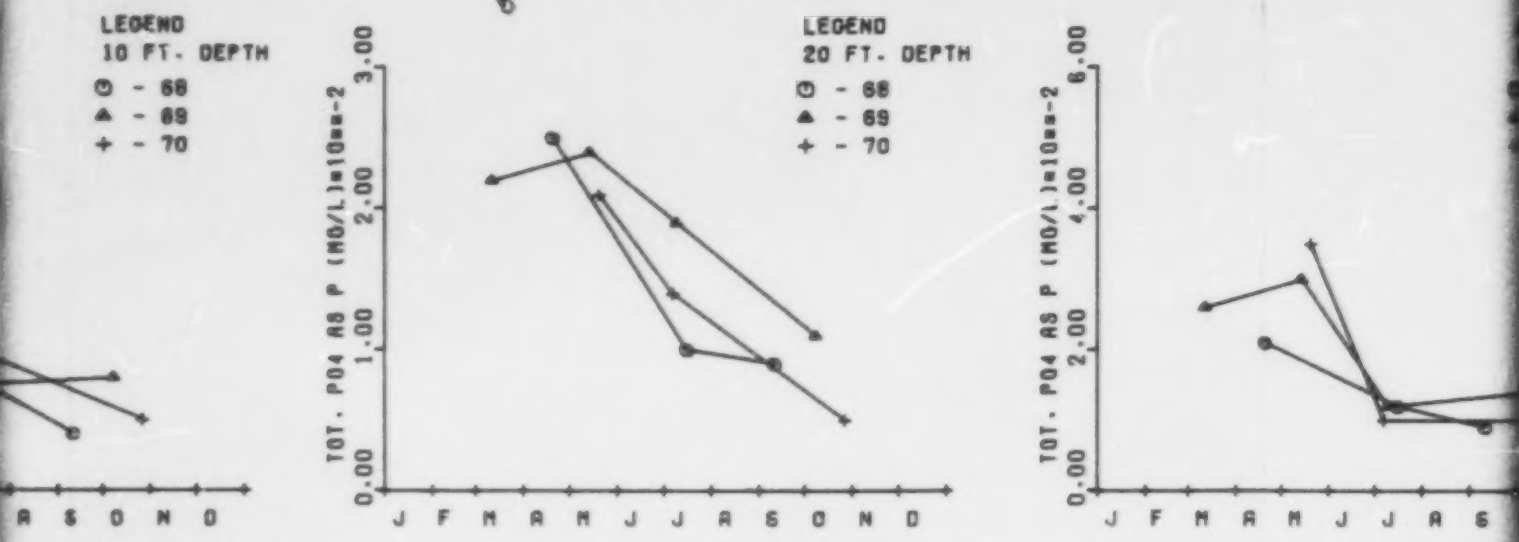

LEGEND
60 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
TOT. PO4 AS P (MG/L)x10**-2
0.00
2.00
4.00
6.00
J F M A M J J A S O N D

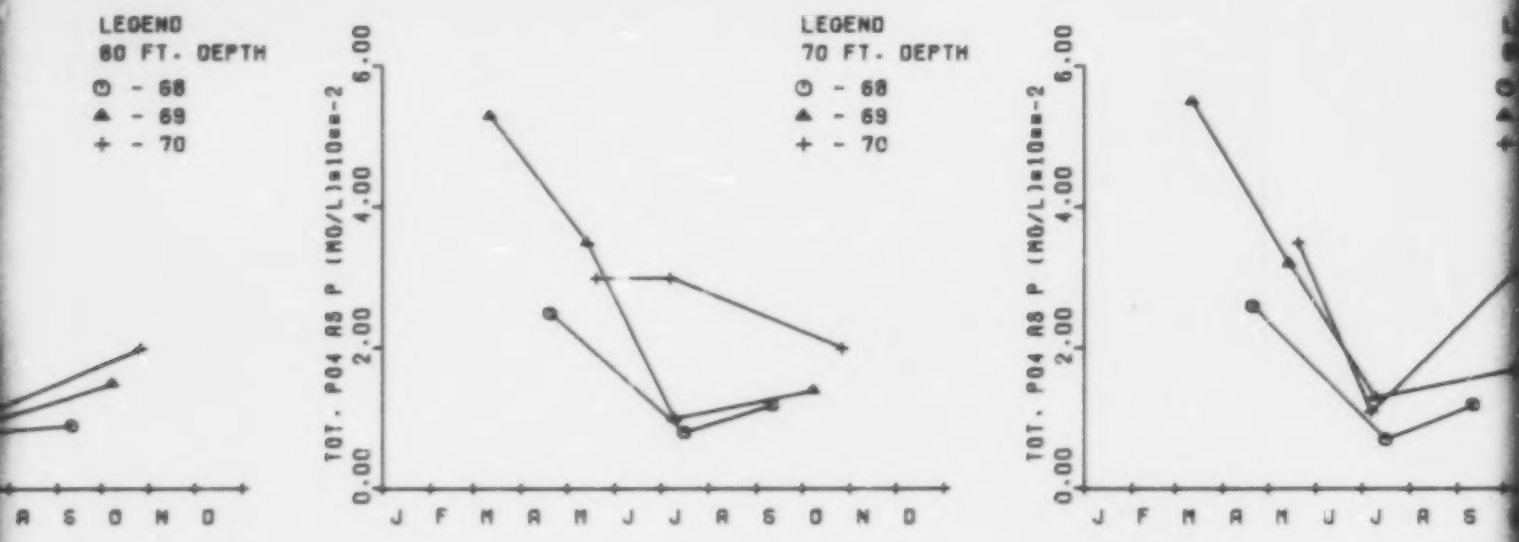
TOT. PO4 AS P (MG/L)x10**-2
0.00
2.00
4.00
6.00

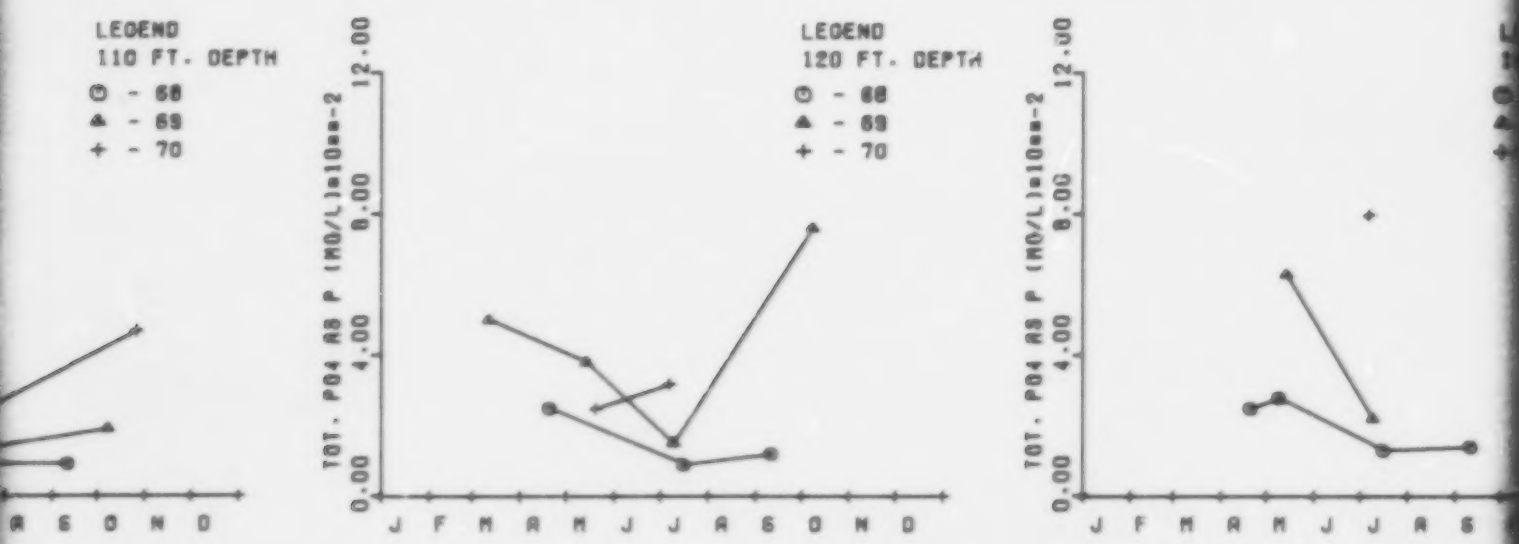

LEGEND
100 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
TOT. PO4 AS P (MG/L)x10**-2
0.00
4.00
8.00
12.00
J F M A M J J A S O N D


LEGEND
110 FT. DEPTH
⊙ - 68
▲ - 69
+ - 70
TOT. PO4 AS P (MG/L)x10**-2
0.00
4.00
8.00
12.00
J F M A M J J A S O N D

TOT. PO4 AS P (MG/L)x10**-2
0.00
4.00
8.00
12.00


LEGEND
10 FT. DEPTH
68
69
70
LEGEND
20 FT. DEPTH
68
69
70
TOT. PO4 AS P (MG/L)=10**-2
0.00
1.00
2.00
3.00
4.00
6.00
J F M A M J J A S O N D


LEGEND
60 FT. DEPTH
68
69
70
LEGEND
70 FT. DEPTH
68
69
70
TOT. PO4 AS P (MG/L)=10**-2
0.00
2.00
4.00
6.00
J F M A M J J A S O N D


LEGEND
110 FT. DEPTH
68
69
70
LEGEND
120 FT. DEPTH
68
69
70
TOT. PO4 AS P (MG/L)=10**-2
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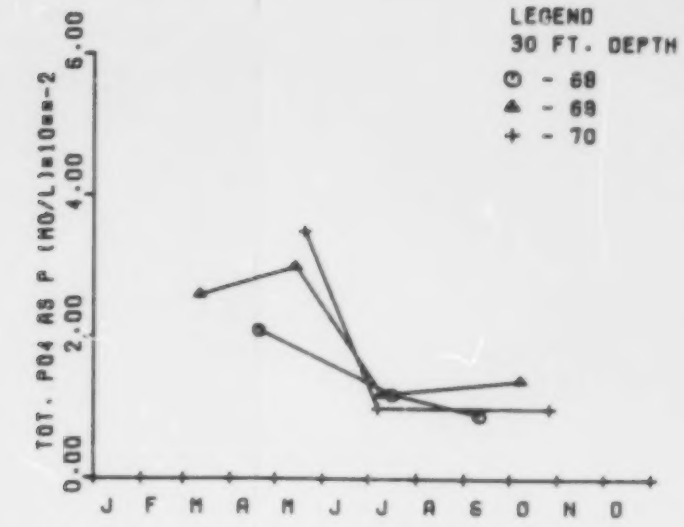
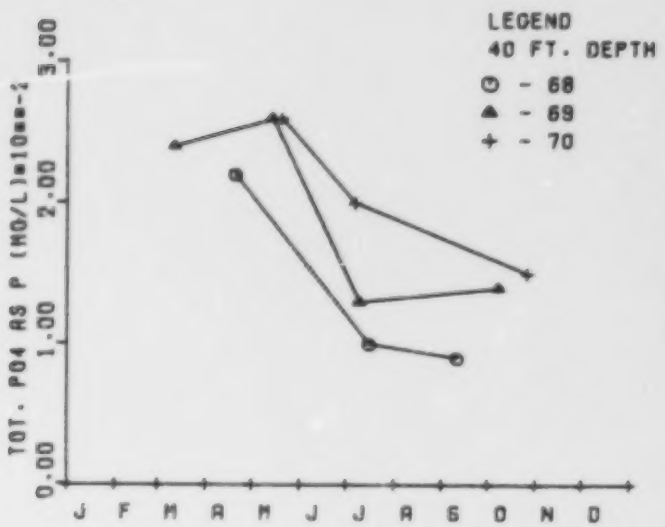
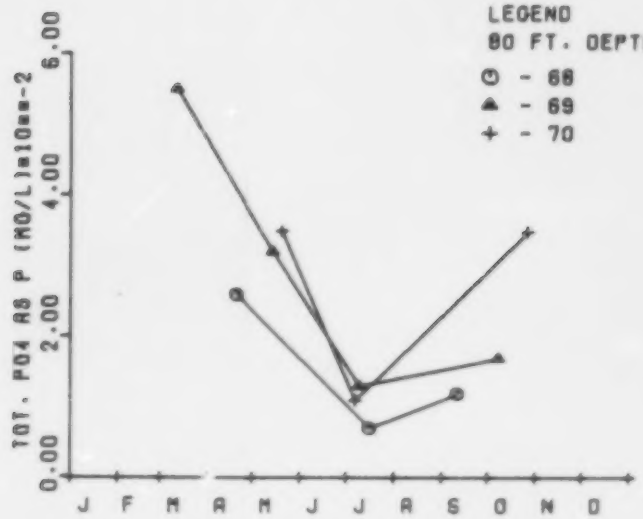
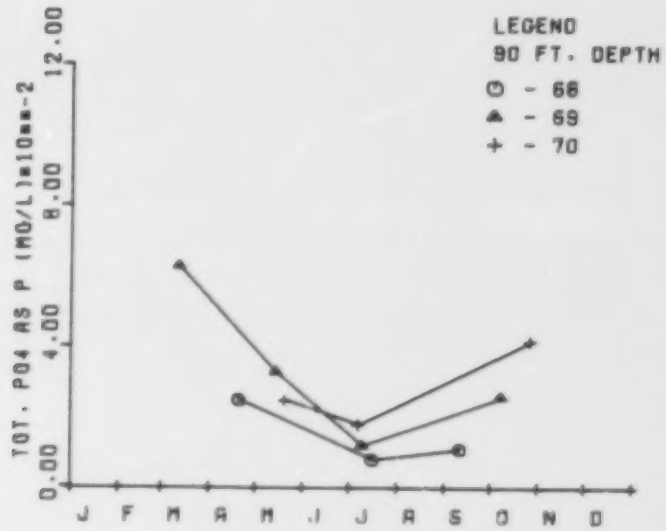
4.00
8.00
12.00
J F M A M J J A S O N D









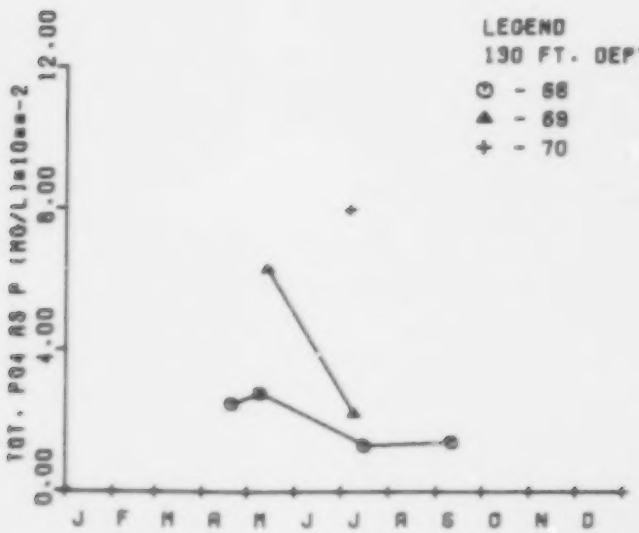
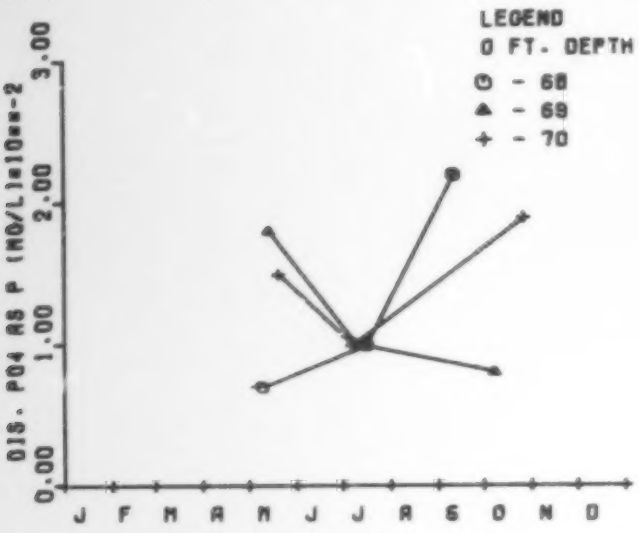


FIGURE 32. Total Phosphate Concentrations of Allatoona Lake at Station 1 for 1968, 1969 and 1970.


LEGEND
0 FT. DEPTH
- 68
- 69
- 70
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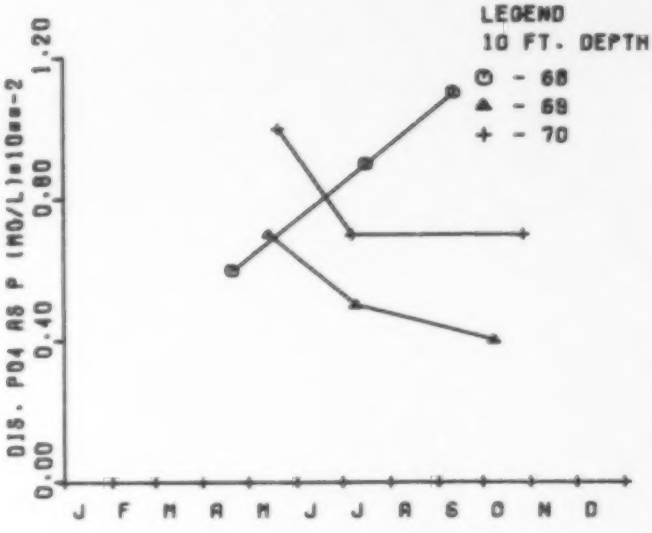
1.00
2.00
3.00
J F M A M J J A S O N D


LEGEND
10 FT. DEPTH
- 68
- 69
- 70
DIS. PO4 AS P (MG/L)=10**-2
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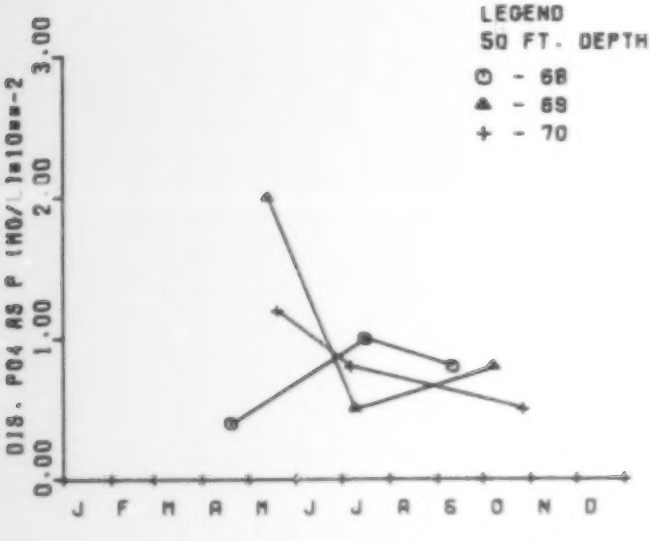
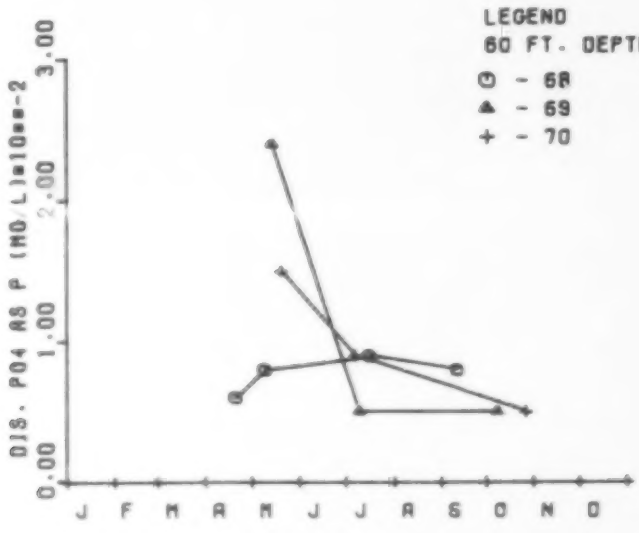
0.40
0.80
1.20
J F M A M J J A S O N D


LEGEND
50 FT. DEPTH
- 68
- 69
- 70
DIS. PO4 AS P (MG/L)=10**-2
0.00
1.00
2.00
3.00
J F M A M J J A S O N D


LEGEND
60 FT. DEPTH
- 68
- 69
- 70
DIS. PO4 AS P (MG/L)=10**-2
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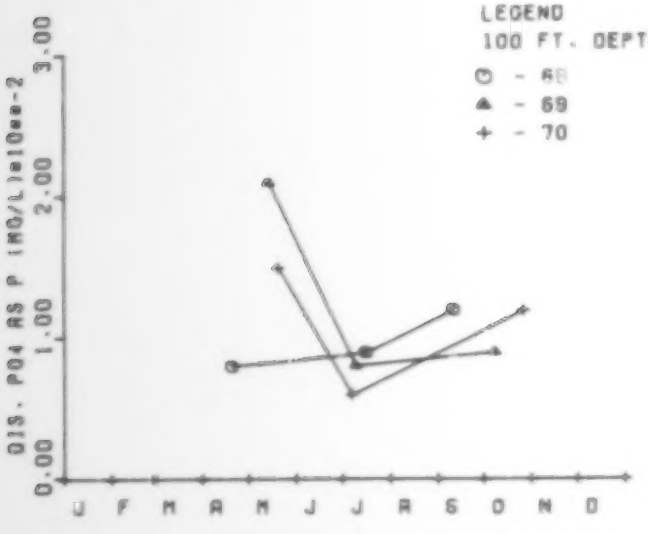
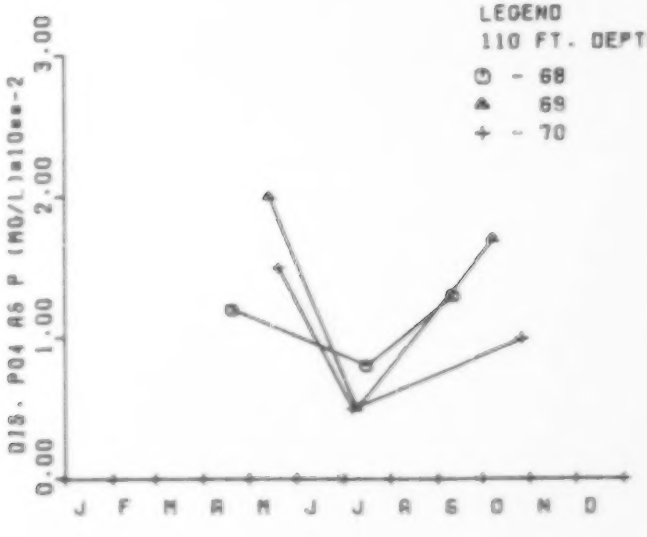
1.00
2.00
3.00
J F M A M J J A S O N D


LEGEND
100 FT. DEPTH
- 68
- 69
- 70
DIS. PO4 AS P (MG/L)=10**-2
0.00
1.00
2.00
3.00
J F M A M J J A S O N D


LEGEND
110 FT. DEPTH
- 68
- 69
- 70
DIS. PO4 AS P (MG/L)=10**-2
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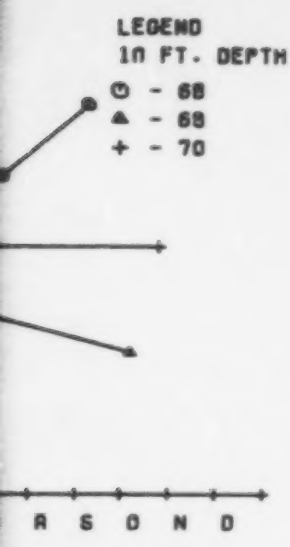
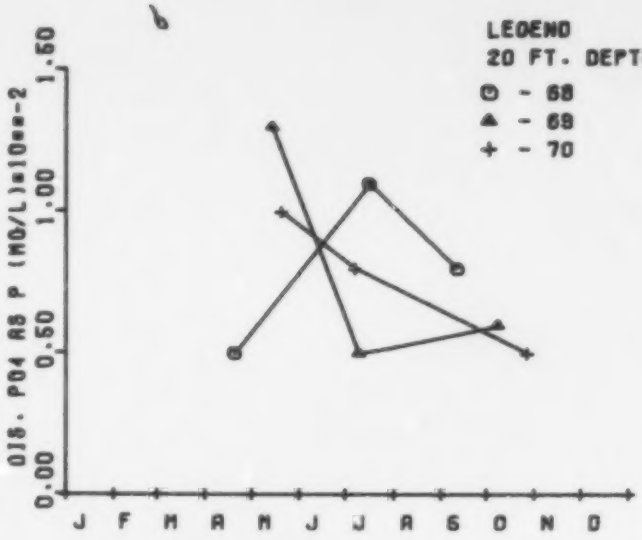
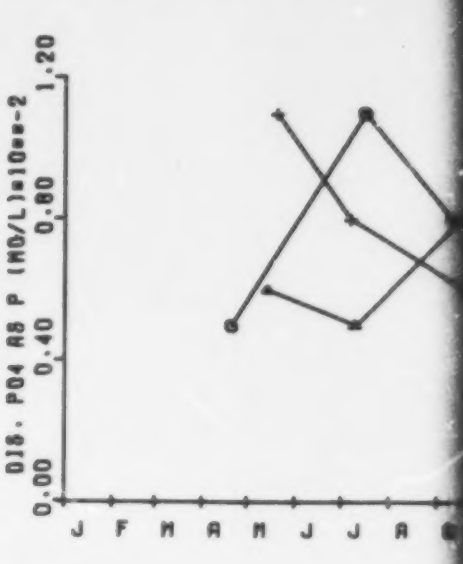
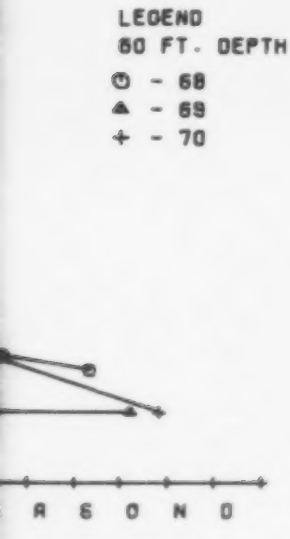
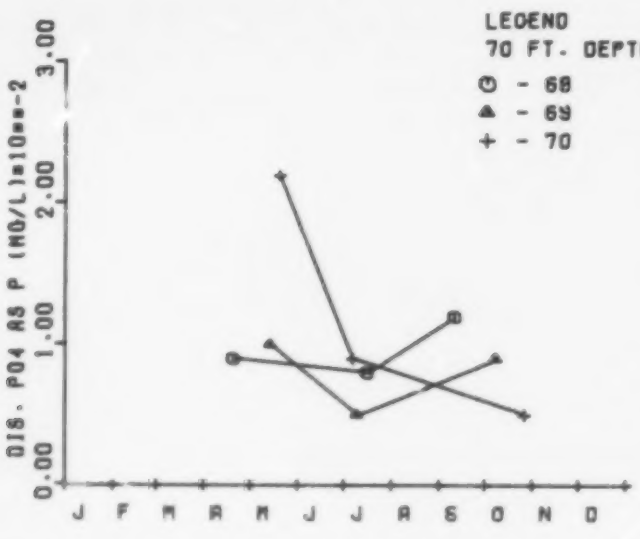
1.00
2.00
3.00
J F M A M J J A S O N D

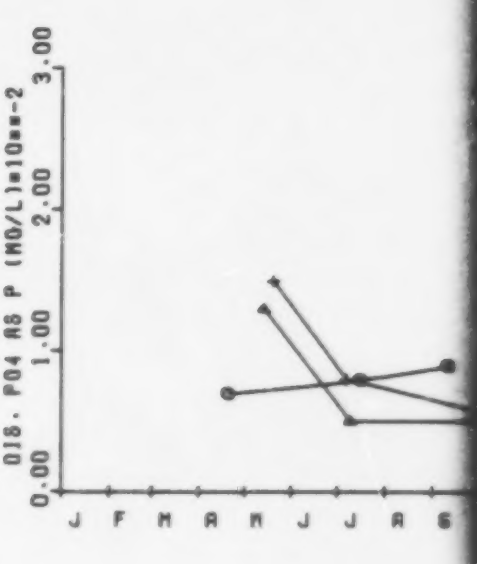

LEGEND
10 FT. DEPTH
68
69
70
A S O N D


LEGEND
20 FT. DEPTH
68
69
70
DIS. PO4 AS P (MG/L)=10**-2
0.00
0.50
1.00
1.50
J F M A M J J A S O N D


DIS. PO4 AS P (MG/L)=10**-2
0.00
0.40
0.80
1.20
J F M A M J J A


LEGEND
60 FT. DEPTH
68
69
70
A S O N D


LEGEND
70 FT. DEPTH
68
69
70
DIS. PO4 AS P (MG/L)=10**-2
0.00
1.00
2.00
3.00
J F M A M J J A S O N D


DIS. PO4 AS P (MG/L)=10**-2
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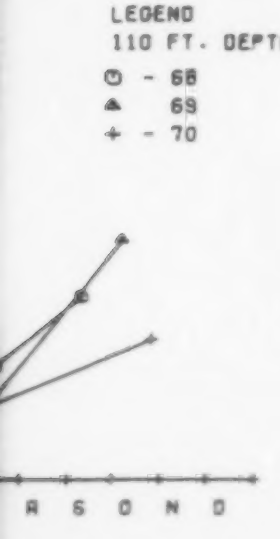
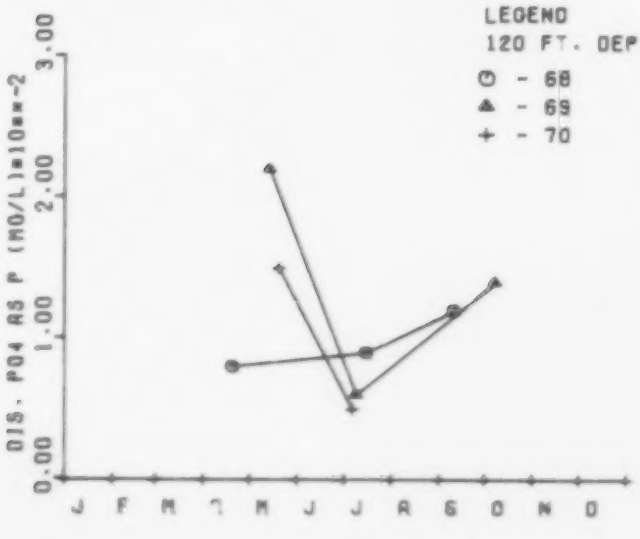
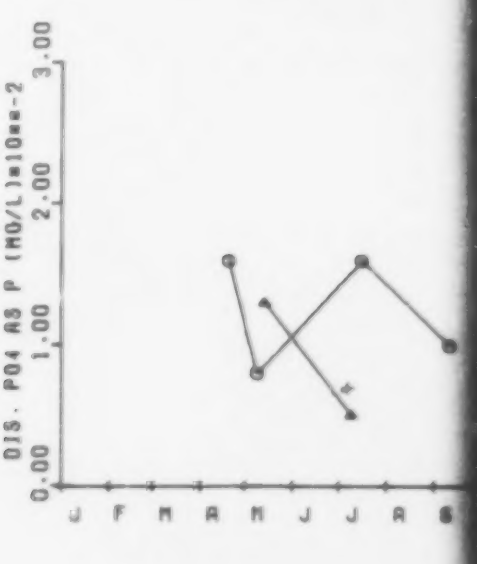
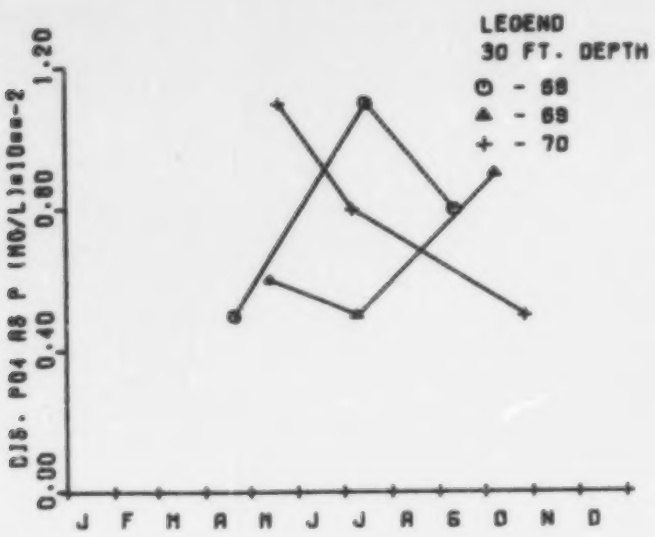
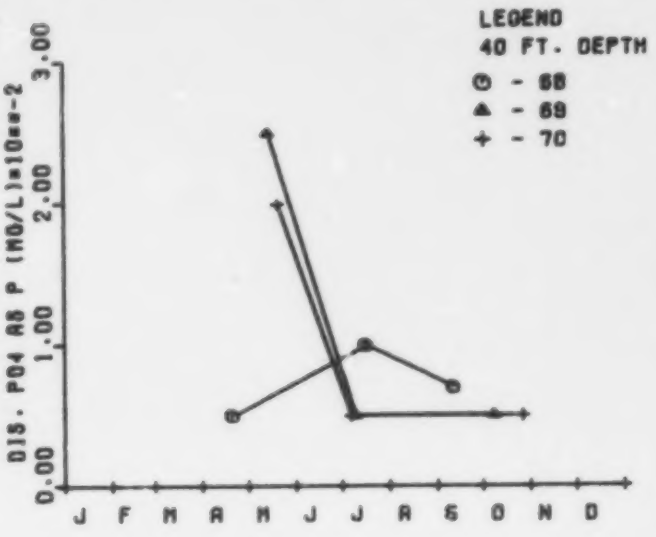
1.00
2.00
3.00
J F M A M J J A

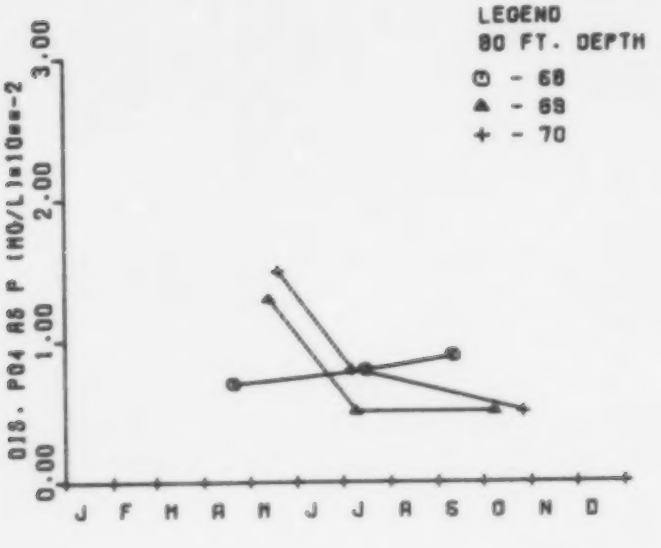

LEGEND
110 FT. DEPTH
68
69
70
A S O N D

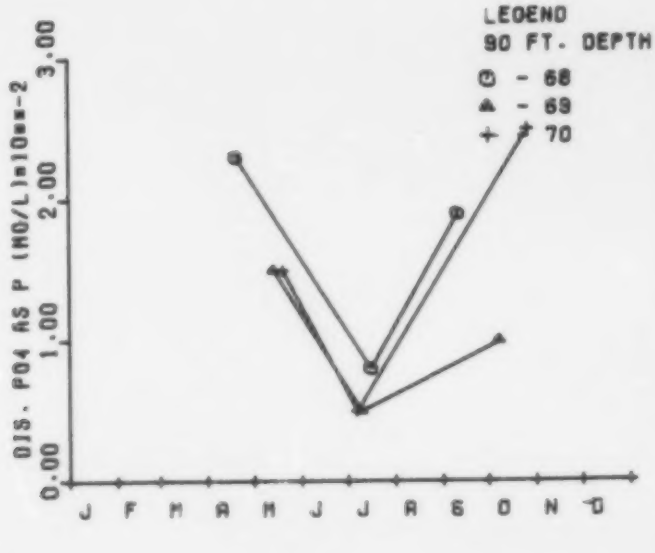

LEGEND
120 FT. DEPTH
68
69
70
DIS. PO4 AS P (MG/L)=10**-2
0.00
1.00
2.00
3.00
J F M A M J J A S O N D


DIS. PO4 AS P (MG/L)=10**-2
0.00
1.00
2.00
3.00
J F M A M J J A









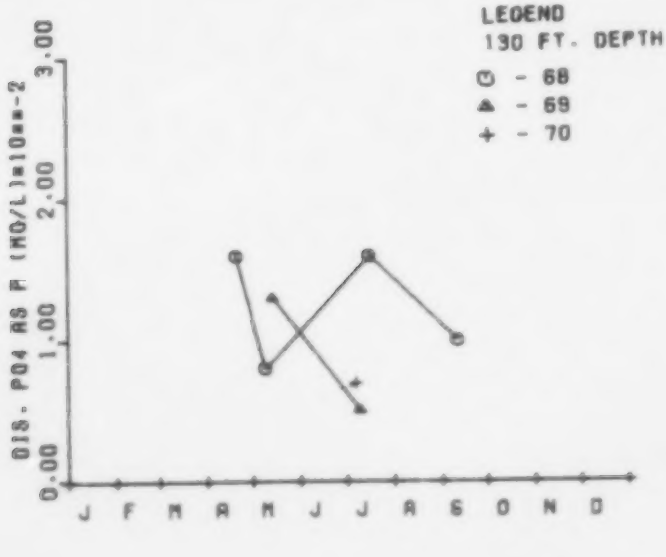


FIGURE 33. Dissolved Phosphate Concentrations of Allatoona Lake at Station 1 for 1968, 1969 and 1970.

Destratification Efficiency

While comparisons in water quality parameters are generally satisfactory for evaluating the effects of artifical destratification on water quality, it is not too useful a technique for evaluating the performance of various types of equipment. In an attempt to evaluate the performance of the diffused air pump operation, two parameters, have been proposed (Symons, 1969). These are defined as:

$$\text{Destratification Efficiency} = \frac{\text{Net change in stability from } t_1 \text{ to } t_2}{\text{Total energy input from } t_1 \text{ to } t_2} \times 100 \quad (1)$$

$$\text{Oxygenation Capacity} = \frac{\text{Net change in oxygen balance from } t_1 \text{ to } t_2}{\text{Total energy input from } t_1 \text{ to } t_2} \quad (2)$$

where t_1 and t_2 are the times of starting and stopping the destratification operation, respectively. (See page 60 of Appendix D)

Destratification efficiency (DE) is dimensionless and expressed as a percent. Oxygenation capacity (OC) has the units pounds dissolved oxygen (DO) per kilowatt hour. The numerator of Equation (2) was determined in this study from the difference in pounds of DO in the hypolimnion (below elevation 820 of the Allatoona Lake) for the control and observed test data.

The destratification efficiency and oxygenation capacity of the diffused air pump operation for the two years study of Allatoona Lake, 1968 and 1969, are presented in Table 5.

Comparison of Equipment Performance Parameters for Various Types of Controls, Allatoona Lake

	1968		1969	
Type of Control	DE %	OC #DO/kw-hr	DE %	OC #DO/kw-hr
Historical Data				
1966-Sta. 1	0.7	1.0	0.3	1.3
1970-Avg. for lake	0.7	0.9	0.3	1.1
Mathematical Model				
AWARE Model			0.3	
Regression Model		1.6		1.4

TABLE-5

The increased operation time of the compressors during 1969 resulted in a 57.4 percent increase in the area under the energy input vs. time curve and a decrease in the calculated DE as compared to 1968. Figure 34 shows that the stability of the mixed lake declined at a rate similar to that which occurs naturally through the months of August and September. The possibility exists, therefore, that values for the DE could be raised by turning the mixing equipment off during this period. Declines in stability that were experienced in 1968 and 1969 might occur naturally, without a corresponding increase in total energy input.

Oxygenation Capacity

Figure 35, and the data in Tables 5 and 6 indicate that the earlier start of the 1969 mixing operation was a benefit in providing additional dissolved oxygen in the hypolimnion of Allatoona Lake. However, the data in Figure 36 shows that the pounds of dissolved oxygen in the hypolimnion began to increase sometime during August or mid September, whether mixing was occurring or not. The rate of dissolved oxygen increase might be a little higher in 1968 and 1969, but this is difficult to demonstrate conclusively. An interesting study would be to determine the behavior of the dissolved oxygen content of the hypolimnion if the mixing apparatus were turned off about this time of year. If the behavior of dissolved oxygen was unaltered by this early shutdown, this would have the effect of increasing the calculated OC of the equipment, because of the decreased total energy input, the denominator of Equation (2).

The dissolved oxygen regression model yielded slightly higher values for OC than did the use of the historical control. Whether these differences are significant is difficult to judge. If additional data had been available for testing the regression model, this possibly could have been adjusted slightly. Then the OC values might have been more consistent with those developed from the historical control.

TABLE 6

Comparison of Minimum Observed Dissolved Oxygen Below Elevation 820

	Unmixed 9/6/66	Mixed 8/6/68	Mixed 8/12/69	Unmixed 7/27/70
Minimum pounds of observed dissolved oxygen below elevation 820	500,000	800,000	1,550,000	1,050,000

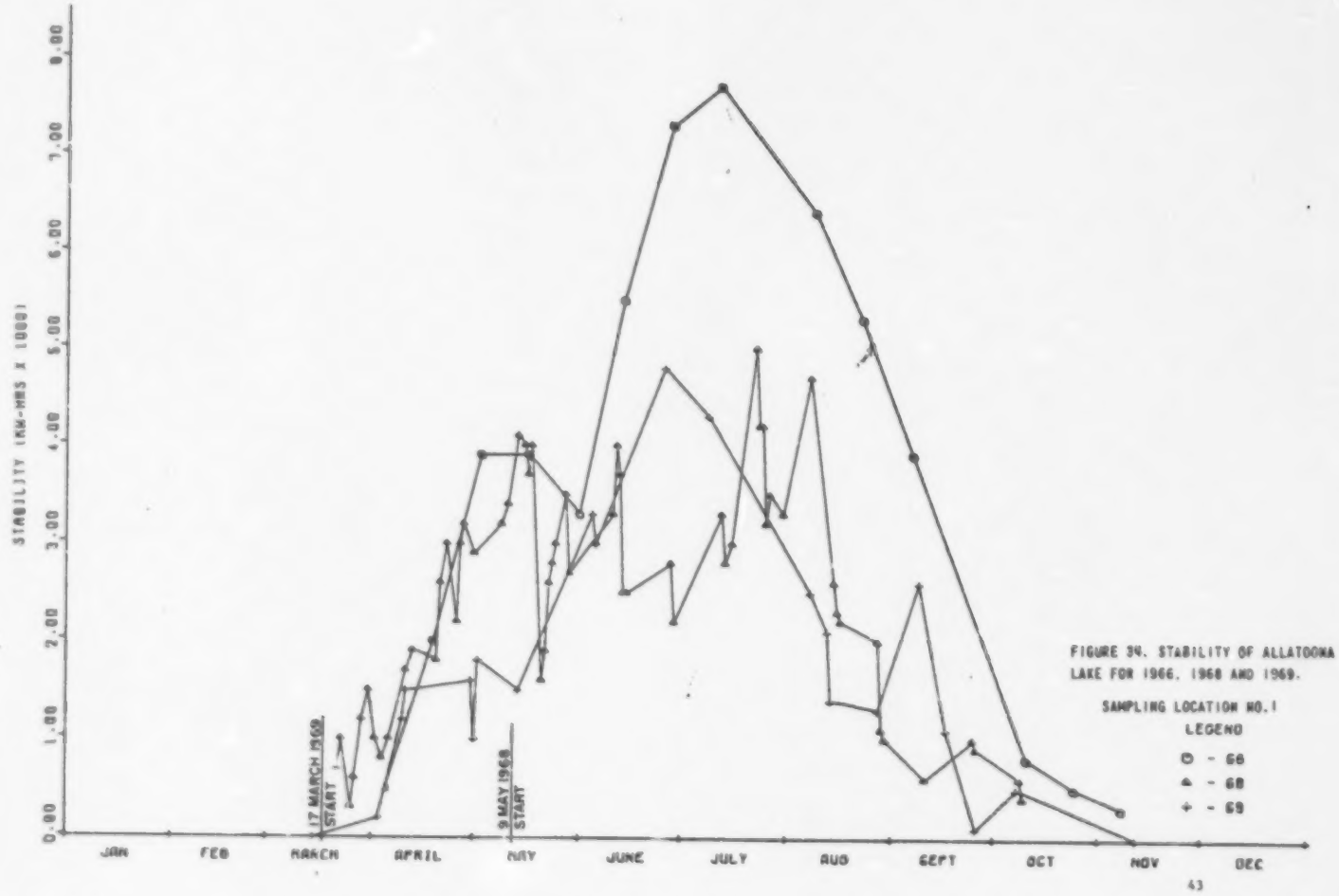


FIGURE 39. STABILITY OF ALLATOONA LAKE FOR 1966, 1968 AND 1969.

SAMPLING LOCATION NO.1

LEGEND

○ - 66

△ - 68

+ - 69

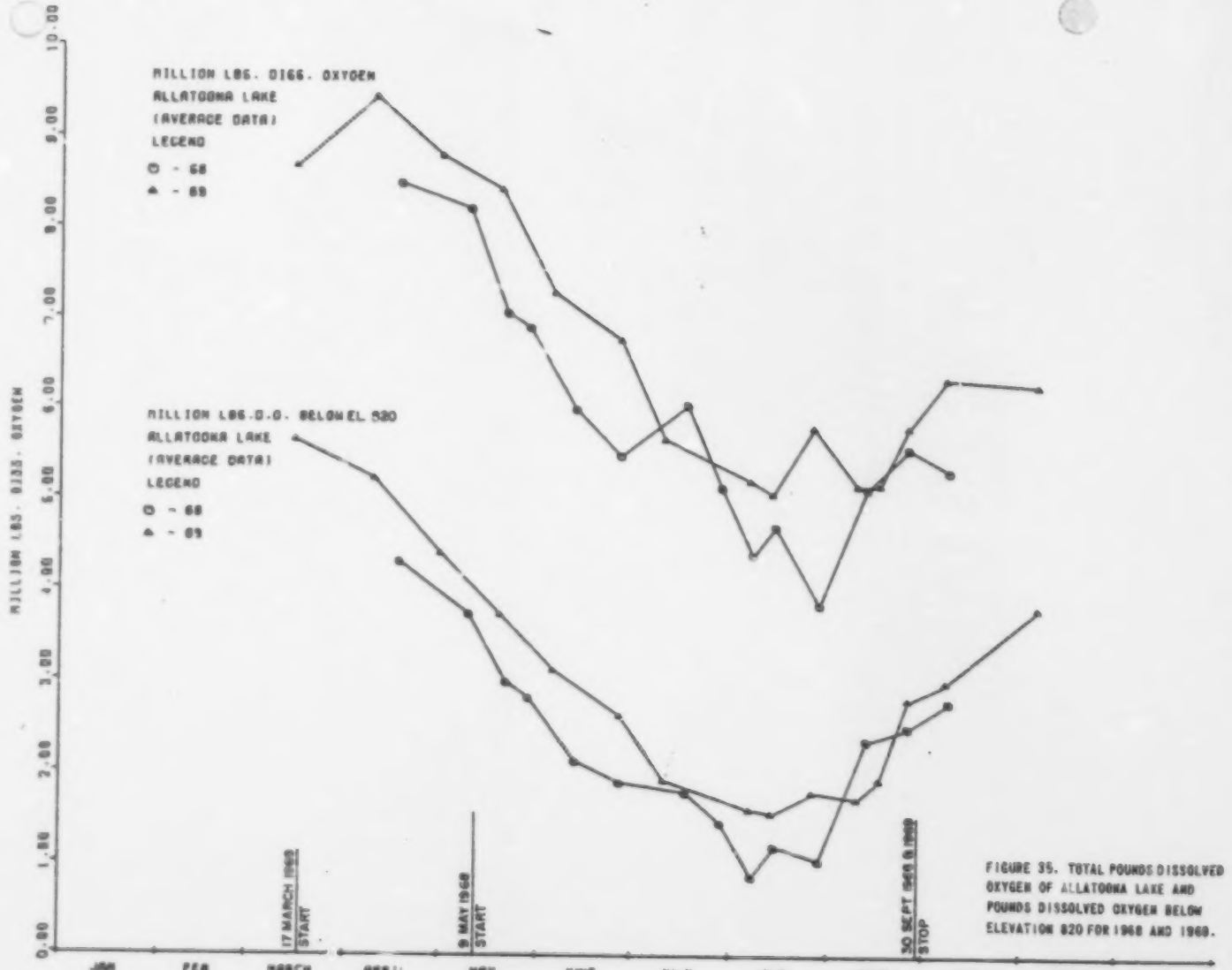


FIGURE 35. TOTAL POUNDS DISSOLVED OXYGEN OF ALLATOONA LAKE AND POUNDS DISSOLVED OXYGEN BELOW ELEVATION 820 FOR 1968 AND 1969.

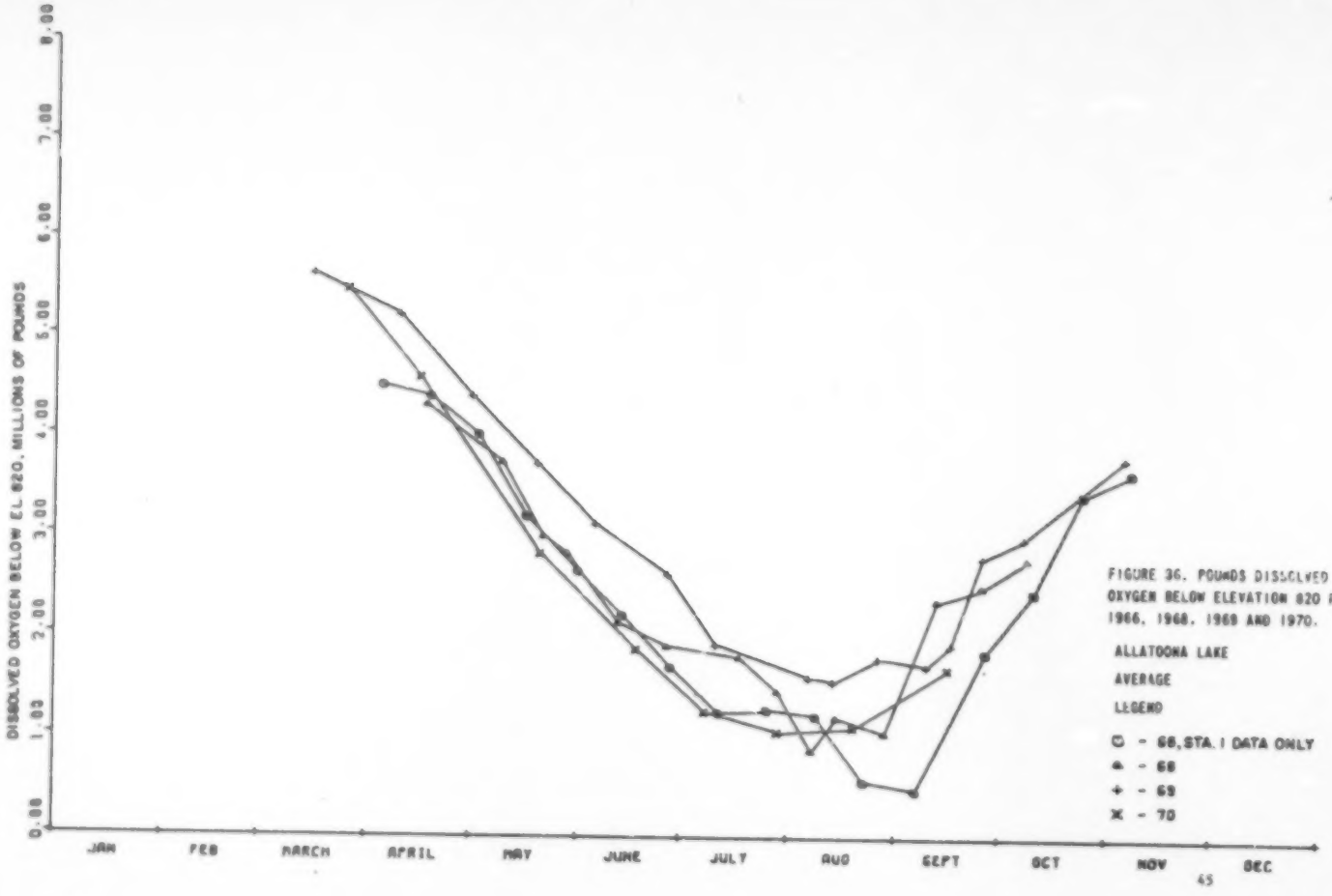


FIGURE 36. POUNDS DISSOLVED OXYGEN BELOW ELEVATION 820 FOR 1966, 1968, 1969 AND 1970.

ALLATOONA LAKE

AVERAGE

BIOLOGICAL ANALYSES AND EVALUATIONS

Biological surveys of Allatoona Lake were conducted in the spring, summer, and fall of 1968-69, spring and summer of 1970 and summer of 1971. The purpose of these surveys was to obtain data needed to determine the influence of artificial destratification on phytoplankton and certain benthic organisms both within the lake and downstream from the dam. Because biological data from past years were not available for the lake, some of the information presented in this report can serve only as background for interpretation of future destratification tests.

BENTHOS

Allatoona Lake

In April 1968, March 1969, both the 1970 studies, and the 1971 study, when the lake was not being artificially mixed, two benthic communities were found in the lake. These were a mayfly and midge community at Stations 5 and 6, and an aquatic earthworm and midge community at all the other lake stations.

The benthic community at the station nearest the diffuser units, Station 1, was altered during mixing. Routine and exploratory dredge hauls near Station 1 revealed that midge larvae were absent during mixing. The bottom muds contained only aquatic worms. Among the most probable causes for this altered community are the characteristics of the lake bottom mud, the effects of currents from lake releases and from the radial diffusers, and predation. This study did not include the chemistry of the bottom muds, so only the latter two possibilities will be considered.

Bottom currents are artificially established near Station 1 by the diffused air pump operation and by periodic releases from the lake. These currents may have reduced the midge population in the following manner. Midge larvae ordinarily live in the lake bottom muds; the most abundant larvae in Allatoona Lake was the phantom midge Chaoborus. These larvae nocturnally migrate from the mud bottom to the lake surface (Welch, 1952, p. 245). Conceivably during migration, water currents could carry many larvae away from Station 1, thus reducing the population appreciably. Conversely, aquatic earthworms (Limnodrilus) remain burrowed in soft bottom ooze and consequently are less disturbed by overlying currents. Dredge hauls may have failed to collect a reduced midge population and merely collected the most numerous bottom dwellers, the aquatic earthworms.

Predation could have also caused the seemingly homogeneous benthic community near the dam. In September 1968, the appearance of freshwater jellyfish (Craspedacusta sowerbii) was noted near Station 1. Hundreds of mature umbrella-shaped medusae were observed surrounding the air bubble columns of the diffusers. These organisms are carnivorous and feed on many small metazoans (e.g., insect larvae, water fleas, copepods). Their predaceous activity on migrating Chaoborus larvae could partially explain the reduced, apparently absent, population of larvae at Station 1 during the September 1968 study.

At other times during mixing, schools of fish were observed around the bubble columns. The amount of fishing testified to the fact that local fishermen felt lake fishing was best near the diffusers during the mixing tests. The reasons for fish to be attracted to the air bubble column area are speculative. Predation on larvae and other small fish-food organisms being transported vertically with currents seemed to be a reasonable theory, but no documentation was made during this study.

ETOWAH RIVER

The Etowah River, 0.7 mile downstream from Allatoona Dam had exceptional clarity during the sampling periods in 1968, 1969, and 1970. Samples were collected at times of minimum release from the lake. At these times, the river was approximately 200 feet wide and less than 3 feet deep. Exposed rock formed an extensive riffle that transected the river. Lush growths of river weed (Podostemum) covered much of the submerged rock in the turbulent riffle. Beds of wild celery (Vallisneria) and pond weed (Potamegeton) bordered the southern shoreline. Often relatively quiet pools were formed near shore in areas where river currents were diverted away. In the late summer, entangled mats of blue-green and green algae dominated the macroscopic flora in these pools. Iron bacteria (Crenothrix) often partially coated the pool bottom and the vegetation with its reddish brown floc. The conditions described above were observed during the two summers of mixing (1968-69) and during the summer without mixing (1970). If there were biological changes in the flora at Station 9 because of the lake destratification, these changes were too subtle to note.

Changes observed in the invertebrate population at Station 9 were subtle also. During the two summers when the lake was being mixed (1968-69), the invertebrate community was relatively diverse. Common gill-breathing immature insects included dragonflies, damselflies, mayflies, and caddisflies. These insects were less abundant during the summer of 1970. Examination of the biotic data showed the apparent population reduction was more closely related to a decrease in oxygen content in the Allatoona Dam tailrace than any other factor observed.

PHYTOPLANKTON

Standing Crop

Phytoplankton studies were conducted in the spring, summer, and fall of 1968 and 1969, and in the spring and summer of 1970 and summer of 1971. Eleven components were considered in analyzing the phytoplankton population for each standing crop study. These included: separation and enumeration of blue-green and green algal forms into their respective coccoid and filamentous categories; separation and enumeration of green and other pigmented flagellates; separation and enumeration of diatoms from inert shells and categorizing centric and pennate forms; and computing total algae.

Findenegg (1965) states that algal composition in a lake may vary from hour to hour. Hence, the importance of standing crop studies is not the recording of slight changes in algal population but rather the recording of a trend toward a pronounced change.

Looking at the lake as a whole, the phytoplankton population was most dense in Little River and in the portion of the lake upstream from Station 4 to Station 6. These areas reached algal bloom portions in 1968 and 1969, exceeding the value of 5,000 organisms per milliliter. Station 6 in July 1961 had an algal bloom (11,098) of pigmented flagellates, Glenodinium quadridens (Stein) Schiller, and Peridinium pusillum (Penard) Lemm. Stations 1 and 2 and Stations 7 and 8 in the Allatoona Creek arm of the lake rarely reached bloom densities. This trend indicated that Little River and Etowah River were adding enrichment (plant nutrients) to Allatoona Lake.

Influence of Mixing

Considering phytoplankton populations as a single parameter, artificial mixing altered only Station 1. For the most part, the following comments are restricted to this influenced area.

Phytoplankton densities at Station 1 occasionally had higher values in 1969 than in 1968. Most evident in these fluctuating values were the near bloom proportions of phytoplankton in the spring of 1969. Samples were collected shortly after artificial mixing began and the increased phytoplankton population may have been the result of this "start-up". As the 1969 mixing test continued, plankton densities became quite similar to those of 1968. This similarity is exemplified by comparing July 1968 and 1969 plankton data. These data show at least one significant change. In 1968 a sharp decrease in plankton was recorded between samples from the 10 and 15 foot depths. In 1969 this decrease was recorded between the 15 and 20 foot depths. One explanation for such a change is more efficient mixing during the 1969 sampling. Two possible causes of increased currents are the operation of an additional compressor in 1969 (installed but not functional in 1968) and greater amounts of water released from the lake in June 1969.

In 1970 when the diffused air pump was not operated, the standing crop at Station 1 was measured again. Mid-summer phytoplankton in the upper euphotic zone showed a decrease in population. At first it appeared that when mixing of the lake was stopped, the phytoplankton population decreased. A comparison of each lake station in 1970 with each station of the earlier studies showed the decreased population existed throughout the lake in 1970. Additionally, the plankton composition changed in 1970. In the summer of 1968 and 1969 a community of mixed coccoid green algae was dominant. In 1970 centric diatoms (Melosira) dominated. The ecological stress that caused the plankton changes of 1970 was never identified specifically. Among the most credible theories is that based upon the recent work of Kilham (1970). His hypothesis is that the ecology of diatoms is strongly influenced by silica concentrations in the water. Also, he states that Melosira is likely to become dominant when silica concentrations exceed 2 MG/L. Specific data are not available on silica in Allatoona Lake.

However other observations (i.e. turbidity, rainfall, and runoff) suggest that silica was higher in 1970 than in the previous two years.

The July 1971 study showed a decrease in phytoplankton population compared to 1968 and 1969. However, it showed an increase over the 1970 summer population. The 1971 study showed a more uniform population to the depth of 20 feet than previous studies as shown in Figure 37. Also, the appearance of more blue-green filamentous algae showed a new trend.

Primary Prpduction

Primary production 1/ studies in Allatoona Lake were conducted in the summer of 1969 and 1970. These studies were performed at Stations 1 and 2. Penetration of incident sunlight was measured using a submarine photometer (submerged photoelectric cell). Light penetration to the one percent transmission level (1% T) was determined and considered the lower limits of the euphotic zone. Intensity of photosynthesis in this euphotic zone was measured by the carbon 14 (^{14}C) method. This method incorporates the use of a tracer, ^{14}C, in the organic matter as a starting point. The technique consists of adding a definite amount of $^{14}CO2$ to bottles of water containing plankton for which the content of CO_2 (total) is known. After proper *in situ* incubation at various depths, the water bottles are recovered and the plankton analyzed. Analyses consisted of determining the content of ^{14}C in the plankton algae after the experiment. Then the total amount of carbon assimilated per square meter per day in the euphotic zone is computed. Details of the ^{14}C method are presented in Steeman-Nielsen's research papers (1951 and 1952).

Mixed versus Unmixed

As previously discussed, the phytoplankton population in 1969 and 1970 were distinctly different. It would be of little value to compare their productivity. A valid comparison of production can be made for each year separately. Stations 1 and 2 were examined for productivity during and following the mixing tests.

During July 1969, primary production was greater at Station 1 than at 2 as shown in Figure 38. Verduin (1956) found that highly productive lakes show yields between 1.8 and 2.4g $C/m^2/day$. Hence, the higher value of Station 1 is well within normal value limits.

Without mixing, July 1970, primary production at Stations 1 and 2 was not significantly different. Yields were less than 0.40g $C/m^2/day$, reflecting the underproductiveness of Allatoona in the summer of 1970.

1/ Primary production is the weight of new organic material created by photosynthesis (Westlake, 1965). It is expressed in this report as grams of carbon assimilated per square meter per day for the entire depth of the euphotic zone.

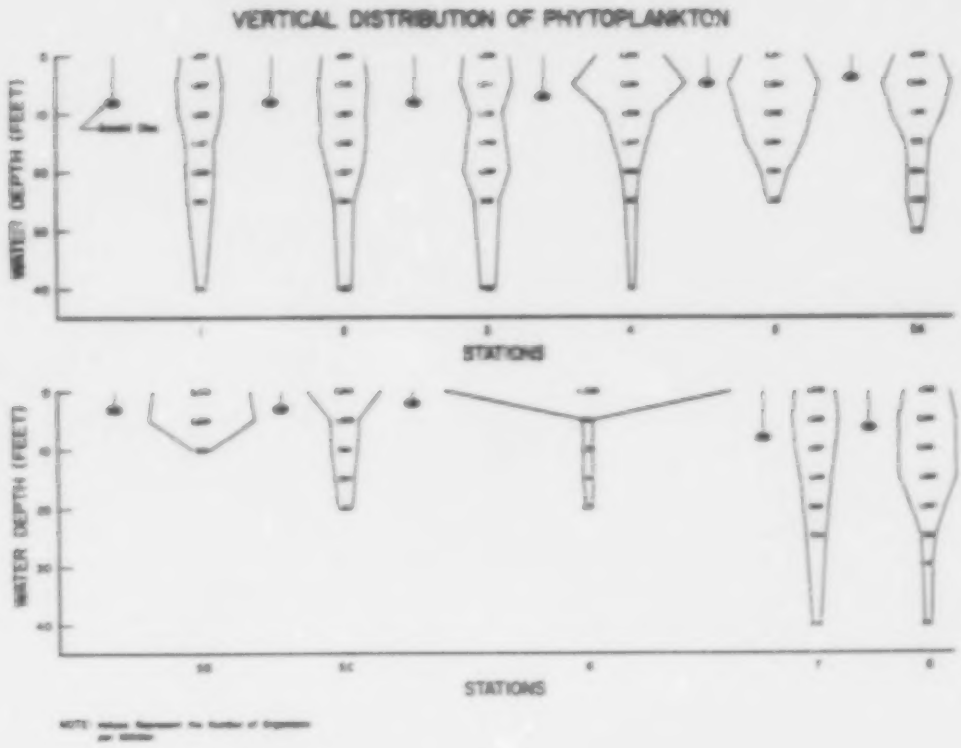


FIGURE 37. Vertical Distribution of Phytoplankton-July 1971.

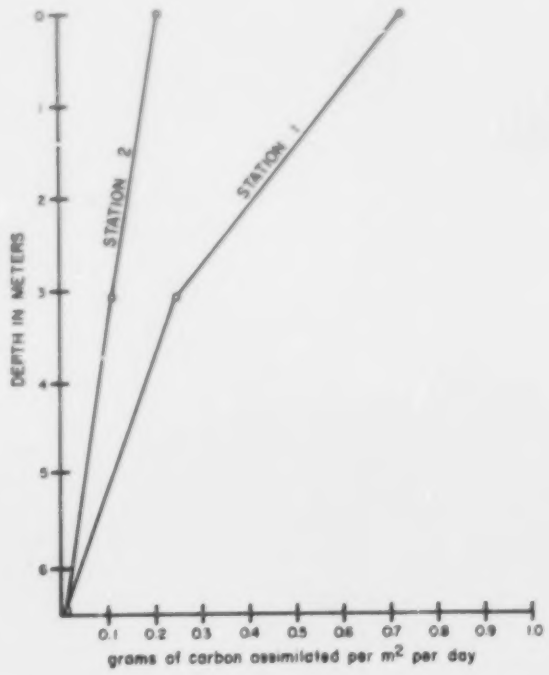


FIGURE 38. Curves Showing the Production of Organic Matter at Stations 1 and 2 in Allatoona Lake (July 1969)

An anomaly appeared when primary production and plankton data for July 1969 were compared. An increase in primary production is usually a reflection of an increase in phytoplankton population. Seemingly, the 1969 plankton population data from Stations 1 and 2 failed to support this statement. Population values obtained by standard Sedwick-Rafter plankton counts (Weber, 1966) were greater at Station 2 than at 1, although primary production values were just the opposite. Conditions causing this "disagreement" could include a difference in species composition, the age, size, and physiological condition of organisms present, and the fact that Sedwick-Rafter plankton counts are only partial. In any case, the important point is that primary production increased at Station 1 (Figure 30) during the operation of the diffused air pump.

Generally, an increase in production is associated with an increase in available nutrients. Recent research (Speece, et al., 1969) shows that aeration systems, similar to those used at the Allatoona project, are capable of transferring nutrients from the hypolimnion up through the euphotic zone into the epilimnion. Research work at the Kerr Water Research Laboratory indicates that the initial increase in productivity is to be expected for the reasons described above. However, these effects may be short term. (See published paper from the Robert S. Kerr Research Center, Ada, Oklahoma.)

BACTERIOLGICAL ANALYSES AND EVALUATIONS

Bacteriological investigations were conducted during April and July 1968, March, May, July and October 1969, and May and July 1970. Evaluations of the water quality with reference to coliform bacteria, and the effects produced by destratification operations on coliform densities and vertical distribution were conducted.

Sample Collection and Handling

All lake subsurface samples were collected in sterile glass containers using a modified JZ bacteriological sampler. Samples were collected at regular depth intervals at most of the stations. Stations having a depth greater than 50 feet were sampled at 20 foot intervals. Stations with a depth less than 50 feet but greater than 30 feet were sampled at 10 foot intervals. Stations with depth less than 30 feet were sampled at five foot intervals.

All stream and lake surface samples were collected using a grab technique. The samples were placed and maintained on ice until analyzed. Most analyses were initiated within four hours of sample collection.

Analyses

Examination of the bacterial data revealed that with the exception of Station 6 and possibly Stations 5B and 5C, the bacterial quality of the lake was excellent. Station 6, located in the upper reach of the lake on the main stem of the Etowah River, was affected by partially treated industrial and municipal wastes from the City of Canton, Georgia. The introduction of these wastes was reflected in the indicator levels detected at Station 6. The monthly mean fecal coliform levels ranged from a low of 110/100 ml in October 1969 to a high of 5100/100 ml in July 1968. Lower fecal coliform densities at Station 6 in 1970 probably reflected improved treatment from Canton's new waste treatment plant. This plant had been operating for about one year with post-chlorination.

Although significant fecal coliform counts were found at Station 6, the impact of these high levels did not affect the lake to any great extent at or downstream from Station 5. As shown in Figure 39, the percent of fecal coliforms present at Station 5 ranged from 1.2 percent to 6 percent of the number present at Station 6 some six miles upstream. The reduction of 94 to 98.8 percent of the fecal coliform population in the six mile reach of the lake may be attributed to such factors as dieoff, dilution, sedimentation, and predation. This process continued downstream and was reflected by values of less than two fecal coliforms per 100 ml at most of the stations downstream from Station 5.

Another area which received treated wastes was the Little River arm of Allatoona Lake. A poultry processing plant near Canton discharges to a stabilization pond prior to discharge to a small tributary of Little River. Based solely on coliform densities at Station 5B (Tables 7 and 8), the waste input in this area would be considered relatively insignificant. Most of the indicator organisms had disappeared before entering the main body of the lake.

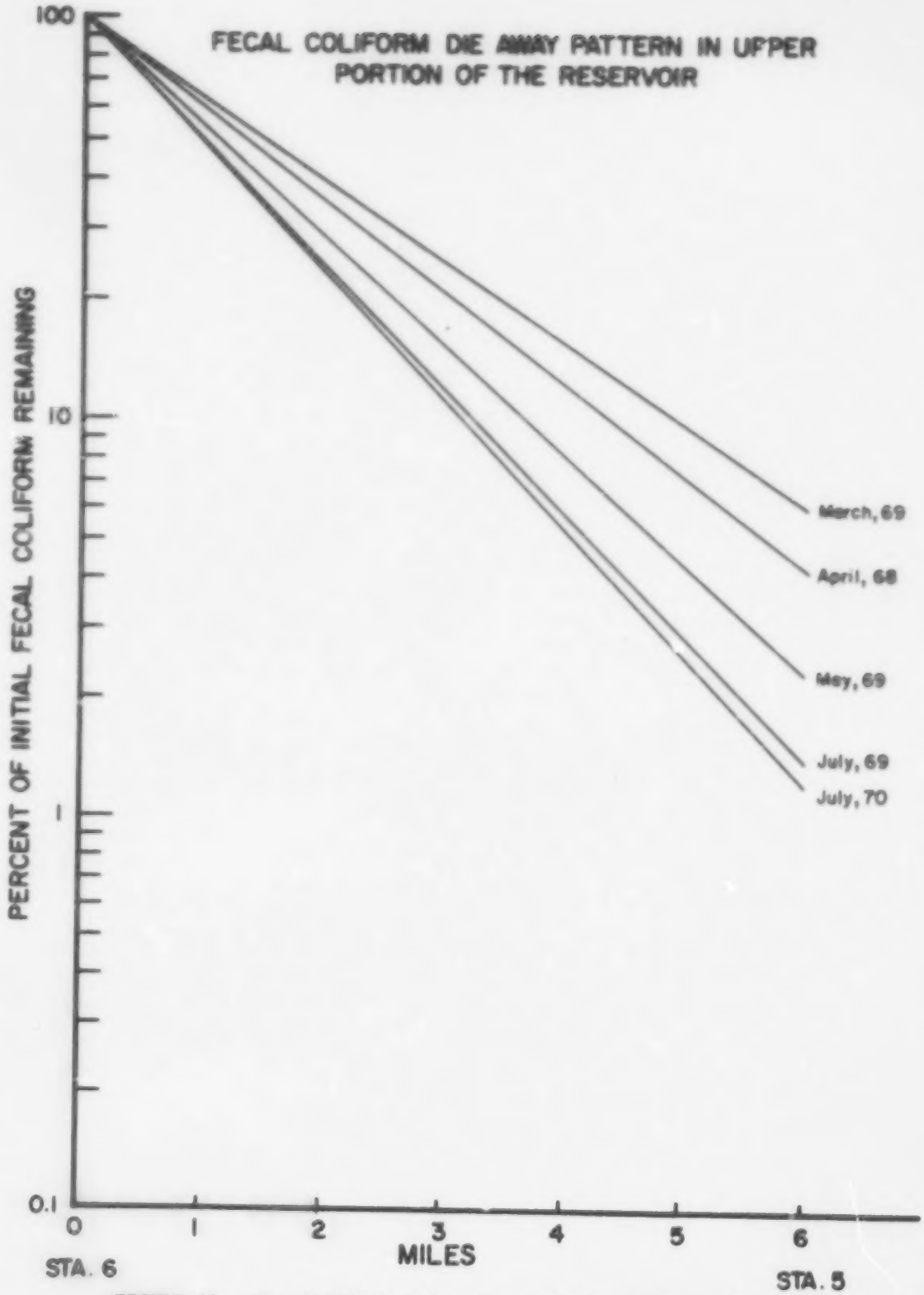


FIGURE 39. Fecal Coliform Die Away Pattern in Upper Portion of the Allatoona Lake.

TABLE 7

Summary of Spring and Summer Total Coliform Data*

Station	1968		1969		1970	
	Apr'l	July	May	July	May	July
1	920	1,000	1,400	880	1,600	3,500
2	100	--	11,000	530	1,600	3,600
3	290	1,700	2,300	640	5,200	1,700
4	580	1,200	6,700	830	3,200	1,700
5	900	620	1,700	1,000	2,000	1,200
5A	--	--	1,300	1,800	2,400	1,500
5B	--	--	6,800	16,000	20,000	8,500
5C	--	--	6,800	5,200	2,500	3,600
6	15,000	5,100	25,000	11,000	16,000	16,000
7	--	--	5,000	410	1,900	1,500
8	270	610	5,700	740	4,300	1,200
9	240	5,800	3,000	6,000	4,000	4,200

* Arithmetic averages per 100 ml

TABLE 8

Summary of Spring and Summer Fecal Coliform Data*

Station	1968		1969		1970	
	April	July	May	July	May	July
1	1	1	--	4	--	--
2	2	--	--	3	--	--
3	2	1	--	2	--	--
4	20	2	--	2	--	--
5	83	40	110	5	--	10
5A	--	--	26	4	2	10
5B	--	--	530	27	230	80
5C	--	--	720	40	23	15
6	2,000	940	4,700	740	790	800
7	--	--	--	2	--	--
8	3	1	--	6	--	--
9	8	11	--	67	--	--

* Arithmetic averages per 100 ml

Although relatively large total coliform densities were encountered at almost every station upon occasion, the corresponding fecal coliform levels were usually low except for those stations previously noted. The high total coliform to low fecal coliform ratios detected during these studies indicate that the total coliform counts had largely been a measure of the Enterobacter portion of the coliform group. This would suggest that a relatively large native coliform population exists in the lake and that it is not directly associated with waste discharges. The presence of large numbers of total coliform organisms in the spring and fall with fewer representatives in the summer suggest that a cyclic pattern exists related in part to seasonal runoff patterns.

Examination of the total coliform data in Appendices A, B, and C and in Figures 40 - 43 reveals a typical pattern with regard to coliform density versus depth. Generally, the coliform density increased with depth, with the higher densities occurring immediately above the mud-water interface. This pattern did not, however, hold true for every individual station or for each study period. Several reasons can be offered for this distribution pattern. Many of the organisms may enter the lake as a result of overland runoff. Runoff introduces not only bacteria but high levels of solids. Many of the bacteria become associated with these solids and with plankton dying within the lake and gradually settle out of the water column. Stratified flow-through patterns vary during the year and this also influences vertical bacterial distribution. The higher densities occurring immediately above the mud-water interface may result from either the cumulative settling or from a native population inhabiting this niche.

A more uniform vertical distribution of coliforms was observed following the fall turnover (October 1969) and during the spring (May 1969) than in the mid summer (July 1969). This indicates that lake mixing and instability not only affect parameters such as temperature and dissolved oxygen, but also play an important role in bacterial distribution.

Data from Station 1 did not show any significant effect on either the coliform density or vertical distribution of coliform resulting from artificial destratification. The relative levels of total coliforms and their distribution at Station 1 during the critical months of July 1968, 1969 and 1970 were remarkably similar. Any effects of the destratification on the coliform patterns should have been reflected at this station.

Mean coliform densities measured at Station 9, below the dam, were generally higher than those measured at Station 1. This could have been caused by animal population, scouring, runoff, and possibly other contributing sources between the Allatoona Dam and Station 9.

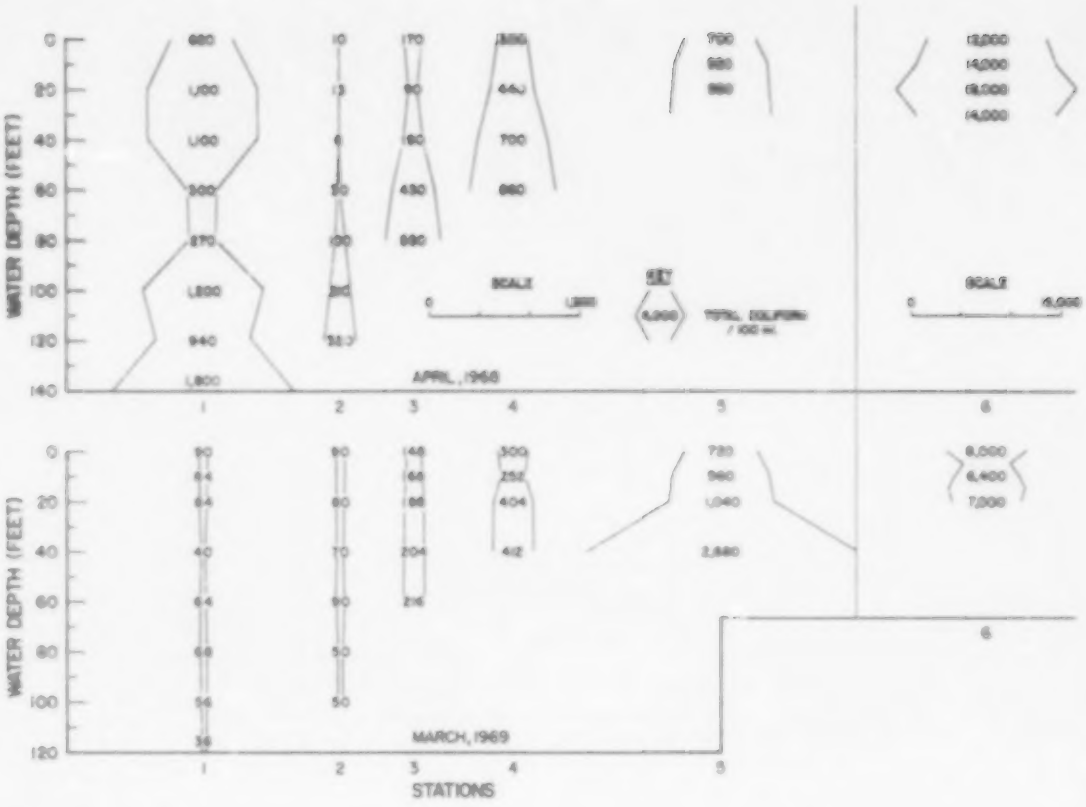


FIGURE 40. Total Coliform/100 ml.

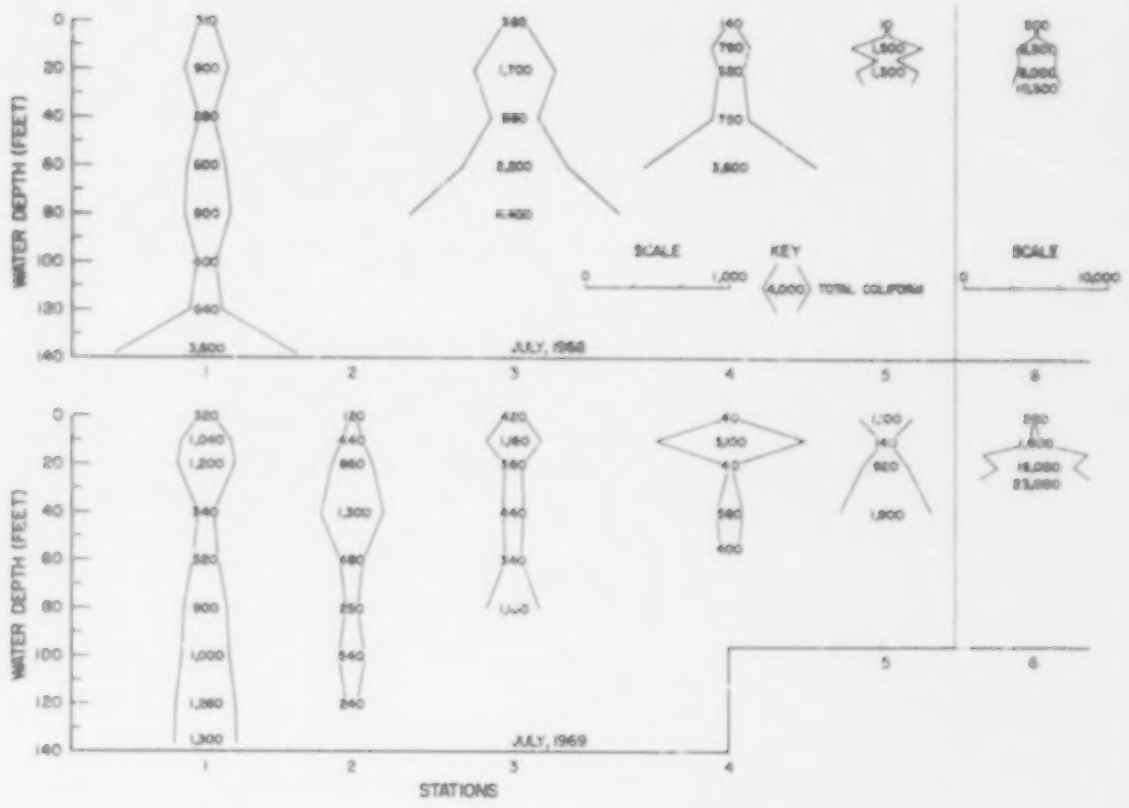


FIGURE 41. Total Coliform/100 ml.

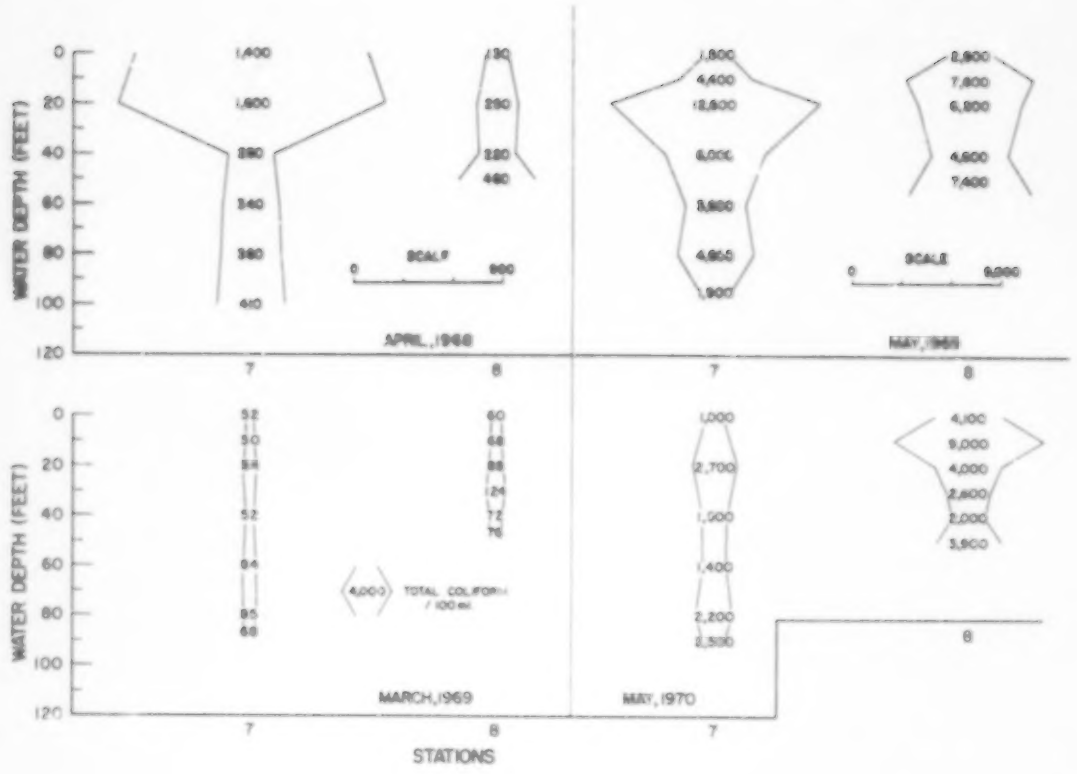


FIGURE 42. Total Coliform/100 ml.

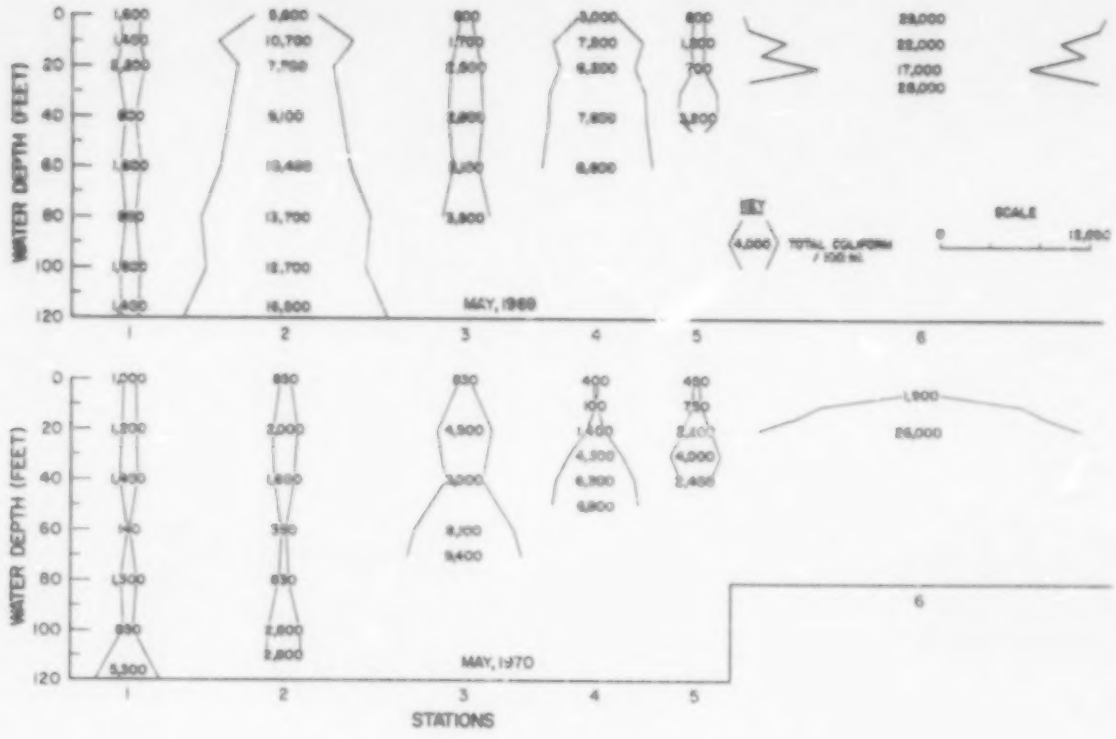


FIGURE 43. Total Coliform/100 ml.

Evaluations

For the most part, the bacterial quality of water in Allatoona Lake is excellent. There are at least two areas, however, where the quality needs improvement. These are the upstream Etowah River arm near Station 6, which is affected by partially treated waste from Canton, Georgia and the Little River arm near Station 5B which is affected by poultry plant waste. These wastes detrimentally affect the lake bacterial quality but only for short stretches.

Based on total to fecal coliform ratios, it would appear that the coliform population is comprised predominately of the genus Enterobacter (Aerobacter). Although high total coliform densities were encountered throughout the lake on occasion, the presence of these high counts is not a direct reflection of waste input. Rather, the high total coliform to low fecal coliform levels suggest that the lake has a native coliform population and that this population is subject to seasonal variations and to storm runoff.

There appears to be a relationship between coliform concentrations and depth. This relationship is seasonal, with the higher densities occurring uniformily in the water column during the cooler months. Several factors such as temperature, stratification and presence of suspended solids in the water appear to have a direct influence on the vertical distribution of coliform in the lake.

Based on data collected at Station 1, no significant influence on either coliform density or vertical distribution can be attributed to artificial destratification.

Any future bacteriological investigations to evaluate destratification should look at a broad spectrum of microorganisms rather than being limited to the enumeration of total and fecal coliforms. Attention must be focused upon the entire heterotrophic population of the lake and the cyclic changes that this population undergoes as a result of such factors as season, runoff, nutrient availability, pH, thermal stratification, and oxygen availability. A thorough understanding of bacterial population interactions and their effects on the nutrient character of the lake is necessary before the overall effect of artificial destratification can be realized. The interrelationship of bacteria, nutrients and algae must be fully explored in order to unravel all of the dynamics of the lake ecosystem.

TABLE-9

COSTS

Itemization of Estimated Yearly Operating Costs Based on Six Months of Continuous Operation and a 5 Year Amortization of Initial System Installation Costs, at 5 1/2 percent.

A. Initial Costs of Equipment and Installation	
(1) Design, Procurement, Fabrication and Installation	$24,579.
(2) Electrical Power Supply Line	7,864.
(3) Electric Compressors	31,480.
(4) Discharge Header Pipe, Flow Valves, Air Supply Lines Air Diffusers, Paint, Marker Buoys, Anchors	18,610.
(5) Security Fence	1,100.
TOTAL	$83,633.
Yearly Amortization of $83,633	19,585.
B. Electrical Power	9,900.
C. Maintenance	1,780.
YEARLY TOTAL	$31,265.

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APPENDICES

Appendix A - Allatoona Lake Destratification Equipment Test - Operational and Water Quality Data. 1968.

Appendix B - Allatoona Lake Destratification Equipment Test - Operational and Water Quality Data. 1969.

Appendix C - Allatoona Lake Destratification Equipment Test - Operational and Water Quality Data. 1970.

Appendix D - Effects of Artificial Destratification on Temperature and Dissolved Oxygen in Allatoona Reservoir by Associated Water and Air Resources Engineers, Inc., Nashville, Tennessee, June 1971.